REINSTATING MEANINGFUL COMPETITION

The notion that the agency should take advantage of all the best proposed technical features in specifying a preferred system is appealing, but analysis shows that multiple design influences from in-house laboratories, weapon centers, operational commands, and contractors often are not compatible and contribute to "goldplating," oversophistication, system integration difficulties, and later performance deficiencies. There is a natural inclination to incorporate new and independently developed subsystems and combine them into a single system specification that then forms the basis for industry competition and later contractual requirements.

Effective competition in system acquisition has been precluded because design decisions on the best approach are made by the Government. Premature commitments are made to a system composed of design contributions from a host of public and private organizations. This "design by committee" approach sets up a one-horse race to meet the mission need, betting on a predetermined and frequently untested combination of technological and performance characteristics. Private sector contractors compete for the development and production of a "required" system, not to offer their best solution at their lowest cost. Consequently, there is limited opportunity for contractor innovation and technical competition, and contractors find it easier to promise the customer what he wants than to innovate and demonstrate new products.

Divided responsibilities for defining the system are also at the heart of later contractual difficulties, correction of deficiencies, and engineering changes, all of which can result in added costs and weakened contractual commitments. Although the contractor has accepted contractual responsibility for completing a system, its ultimate cost, schedule, and performance difficulties are rooted in the combination of specified performance requirements the agency believed could be met. Thus, ultimate responsibility for development problems is difficult to pinpoint.

In most programs, important advantages could result from allowing competitors to be independently responsible for the evolution of their systems by:

- Reinstating a competitive challenge to industry to use a wider span of technologies for system solutions that are of lower cost and simpler design

- Creating incentives that encourage economy and austerity in development because, unlike sole-source situations, the incentives for competitors can be directed toward austerity in system design and system design activities

- Restoring the integrity of contracts, with each contractor fully responsible for designing the system contained in its proposal. Ultimately, system demonstration should determine the success or failure of a contractor's approach and there should be a sound basis for negotiating a production contract.

A wider latitude for contractors to propose and explore system alternatives would be balanced by technical competition among them. These are not unlimited alternatives or alternatives for their own sake, but options pursued as long as they make sense in terms of their cost, what has been learned and what remains to be learned in order to make stable program commitments. Initially, only relatively small amounts of money will be needed to explore system concepts to determine the ones that are the most promising and the ones that should be rejected.

Recommendation 6. Maintain competition between contractors exploring alternative systems by:

(a) Limiting commitments to each contractor to annual fixed-level awards, subject to annual review of their technical progress by the sponsoring agency component.

(b) Assigning agency representatives with relevant operational experience to advise competing contractors as necessary in developing performance and other requirements for each candidate system as tests and tradeoffs are made.

(c) Concentrating activities of agency development organizations, Government laboratories, and technical management staffs during the private sector competition on monitoring and evaluating contractor development efforts, and participating in those tests critical to determining whether the system candidate should be continued.

Choosing Preferred Systems

The choice of a system can be based on low-cost information—studies, analyses, and limited laboratory tests—but this is also low-confidence information whenever a system embodies advances in technology. Although the short-range benefits of money saved by an early choice of a system are apparent, the penalties of a poor early choice can and have proved to be enormously costly.

Early choice of a system raises the risk that increasing costs will have to be paid as long as the agency need remains of sufficient priority. With only a single organized effort underway to meet the need, system performance and schedule slippages have to be accommodated by additional funding. As a result of this monopoly-like situation, costly and burdensome controls and regulations must be applied to a greater extent than in competitive procurements to assure public accountability. There are no *standards* to measure the efficiency of a single undertaking and no competition to aid in choosing the best system.

Technical leveling through transfusion of the best features of proposals early in system exploration and, later, during source selection narrows the differences between competing proposals. Source selections have depended less on technical differences between proposals and more on contractor predicted costs at a time of great technical uncertainty about the "chosen system." In relying on these cost predictions for initial system procurement, insufficient weight has been given to system performance and to the cost eventually to be paid for operating, supporting, and maintaining the system.

Systems that were defined early and subjected to a short industry competition to select the contractor and remaining design refinements invariably have led to technical problems and contractual difficulties. The resulting procurement climate has been clouded by buy-ins, contentious awards, and contracts that were subject to so many changes and claims as to invalidate the integrity of original contractual agreements.

Some new DOD programs reflect efforts to first prove out the "chosen" system by building partial or complete prototypes. This is a major improvement. However, in new prototype programs, choices of technical approach and some system characteristics are still being made by the agency before competition takes place. Introducing industry competition after a system has been largely defined and when large-scale commitments for prototypes have to be made results in relatively narrow cost and technical differences and confines the participation to major firms.

Competitive demonstration of new systems is not appropriate for all programs, but the decision to forego competition should consider more than near-term savings in time and money. The added expenditure of R&D monies to bring a wider span of system solutions into competition can be expected to have a great leverage effect on ultimate system performance and on the vast majority of program costs that will be incurred later.

Looking at the past and to the future, no new programs automatically can or cannot afford competitive demonstration as a basis for choosing a preferred system. It is deceiving to say from the outset that any systems which might meet an agency need must of necessity be big and expensive and, therefore, not amenable to prototype demonstration. The "necessity" for bigness comes about mainly because of familiarity with the scale and scope of past systems used to meet comparable agency needs. With a wide range of system candidates and technologies opened up by earlier recommendations, smaller and cheaper systems will have a chance to be brought forward.

If several design teams were allowed to follow different technical paths in the early innovative phase of system acquisition, the agency might select two for competitive demonstrations of either complete systems or prototypes that embodied all the critical parts.

Having competition from the beginning of the program and maintaining it to this point would provide important benefits largely lacking in current programs, including:

- Design continuity from concept through engineering design to improve technical control and integrity of the system

• Different competitive performance and cost solutions to provide options

• Clear contractor product responsibility for a system.

Competitive exploration of technical approaches should produce distinguishably different system performance characteristics. Technical differences would then become more important criteria for choosing systems and contractors than in the past when differences mainly involved design detail and an uncertain cost.

Essentially, our recommendations call for using additional R&D expenditures to initiate competition before system options are eliminated and when costs are significantly lower than those that must be incurred later for full-scale engineering development. Competition should be continued at least up to the final development phase to provide a sound basis for choosing a potential system and entering into firm performance and price commitments with the successful developer.

Recommendation 7. Limit premature system commitments and retain the benefit of system-level competition with an agency head decision to conduct competitive demonstration of candidate systems by:

(a) Choosing contractors for system demonstration depending on their relative technical progress, remaining uncertainties, and economic constraints. The overriding objective should be to have competition at least through the initial critical development stages and to permit use of firm commitments for final development and initial production.

(b) Providing selected contractors with the operational test conditions, mission performance criteria, and lifetime ownership cost factors that will be used in the final system evaluation and selection.

(c) Proceeding with final development and initial production and with commitments to a firm date for operational use after the agency needs and goals are reaffirmed and competitive demonstration results prove that the chosen technical approach is sound and definition of a system procurement program is practical.

(d) Strengthening each agency's cost estimating capability for:

(1) Developing lifetime ownership costs for use in choosing preferred major systems

(2) Developing total cost projections for the number and kind of systems to be bought for operational use

(3) Preparing budget requests for final development and procurement.

RECOMMENDED ACQUISITION STRUCTURE FOR PROGRAMS NOT BASED ON COMPETITIVE DEMONSTRATION

Some large or complex systems cannot be put through competitive hardware demonstrations, as in the case of large aircraft carriers: an early choice of a preferred system may be necessary. Programs like Apollo and Polaris that made an early commitment to an undeveloped system have generally been considered successful when accompanied by these essential conditions:

• There was a broad consensus that cost was not as important a program goal as mission capability and/or the time it was to be achieved.

• The Government retained direct control and responsibility for defining and developing the system through a highly competent program staff and gave itself flexibility to change system characteristics and performance "requirements."

• Flexible cost-type contracts were used for specially selected contractors.

Such programs were usually of high priority because they addressed mission needs that were critical to national policy and strategy. They received the specific attention of the President and the National Security Council; thus, the programs attracted large amounts of agency resources and the best talents from industry and Government to solve major technical problems.

Two important criteria for adopting a direct agency control approach are:

• Some urgent needs cannot be met if time is taken to explore eligible alternative systems to a point when competitive hardware test information is available. Instead, a system concept must be formulated early by taking (transfusing) the best ideas from industry and Government and by applying large-scale resources to achieve a solution within a fixed time.

- Some needs and goals will require major systems of such massive physical and financial magnitude that no one contractor (or even a team of contractors) may be able to marshal, consolidate, and manage all the necessary talents and resources to compete, even if the agency could finance them.

Both the criteria for choosing such an approach and the conditions needed to make it successful clearly suggest that these programs will often require the highest levels of visibility. They should be subject to agency head review of the reasons for adopting a centralized format and be reviewed in Presidential and congressional councils when the resources or capabilities required are critical to national planning.

Although these programs warrant special controls, overreliance should not be placed on complicated regulations and contractual clauses. Better assurance of program success can be attained from proper contractor selection and the involvement of a strong, technically competent program management office complemented by a strengthened agency test and evaluation capability.

Recommendation 8. Obtain agency head approval if an agency component determines that it should concentrate development resources on a single system without funding exploration of competitive system candidates. Related actions should:

(a) Establish a strong centralized program office within an agency component to take direct technical and management control of the program.

(b) Integrate selected technical and management contributions from in-house groups and contractors.

(c) Select contractors with proven management, financial, and technical capabilities as related to the problems at hand. Use cost-reimbursement contracts for high technical risk portions of the program.

(d) Estimate program cost within a probable range until the system reaches the final development phase.

Implementation: Final Development, Production, and Use

Although the benefits of competition apply equally to the final development, production, and operation of systems, the cost to maintain competition rises substantially in these phases. As a consequence, systems normally enter final development, production, and deployment under an evolved monopoly situation; there is only a single system and contractor to cope with an agency need. Recent difficulties in getting systems produced and deployed within contract terms are related to the "locked in" position of a contractor who, since the beginning of development, has not been subject to direct competitive pressure.

The basic problem, however, is not being locked-in to a sole-source contractor but being locked-in to one who, as it turns out, cannot supply the system as originally planned under the terms and conditions of the contract. Following our recommended acquisition pattern, the contractor and his system would be brought to a point where contractual obligations could be made *before* competition was eliminated with high assurance that he *could,* in fact, supply the system according to plan.

Although the chosen system would have been created and demonstrated under continuous competitive pressure, there are conditions when direct competition should be retained or reinstated to drive ownership cost down and system performance up. For example, when the operating conditions remain very uncertain, as in the case of some defense systems, the cost of having competing operational systems with different capabilities may be an acceptable price to pay for the benefit of competition and for being prepared for operational contingencies.

In another situation, the system chosen to meet the need may have to be procured in large quantities over an extended period. If the cost of duplicating tooling, facilities, and knowhow is not prohibitive, it can be advantageous to establish competing producers. Finally, when total systems cannot be competed in the implementation stage, the prime contractor will find it beneficial from his viewpoint and the Government's to solicit competitive sources for selected subsystems. Practices to retain or reinstate competition are followed on occasion by DOD and should be continued whenever the benefits of doing so justify the additional investment of time and cost. The difficulty, of course, is that while the cost of maintaining competition can be readily determined in advance, the benefits cannot.

Problems associated with the final development, production, and use of new systems have been the most painful symptoms of basic inadequacies in the structure of system acquisition programs. Defense systems have been produced and deployed in large numbers while major unknowns about their technical capabilities, reliability, and operational effectiveness remained. Operationally deficient and unreliable systems have often resulted.

Two kinds of cost problems have come to the forefront during these later phases. First, the unit cost of each new system has been rising over the cost of predecessor systems to meet similar needs. Second, major systems in the final development and production phases have grown in cost well in excess of planned amounts so that the agency often is forced to:

- Shift money between programs and sometimes obtain reprogramming authority from Congress
- Obtain higher than planned appropriations from Congress in succeeding years
- Reduce the number of units to be procured and deployed (force levels).

DOD has taken various actions to alleviate the cost growth problem, including strengthening its cost estimating capability for major systems. These efforts will not reduce the rising unit cost of new systems and resultant reductions in planned force levels unless other more basic changes are made in how needs and goals are initially set and how systems are then defined, competed for, developed, tested, and evaluated.

The intended cumulative effect of our recommendations is to acquire enough information to choose systems within established agency cost goals, to change the contracting environment to one of competitive demonstration, and to minimize the difficulties in present-day contract administration. To support all these recommended actions, strengthened agency testing is necessary.

One of the primary findings of our study is that too much is committed to individual major systems before ideas, needs, designs, and hardware are tested and evaluated. Agency testing has usually been delayed until the results were too late to be used effectively in an overcommitted program. Additionally, the testing function has borne the brunt of problems created by the way early acquisition processes have been conducted.

Testing, in the major system acquisition process, has not commanded the importance, stature, or priority that it must if it is to be a primary source of information on major system progress and for decisions on continuing system design efforts, system selection, starting production, and operational deployment.

There are two main reasons why there has been inadequate testing. First, testing is often expensive and time-consuming, especially if staged and executed in a realistic manner. Second, the advocates of major system programs are aware that negative test results, if misunderstood at higher levels, can jeopardize or delay a program.

There is mounting evidence that agencies should spend the money, take the time, and go to the trouble of performing adequate tests. DOD has taken initiatives to strengthen testing by:

- Establishing a top-level office to set policy and to monitor, for the Secretary, the test operations of the military services
- Emphasizing earlier development and operational testing in new programs and readjusting some of the testing in ongoing programs
- Reducing the overlap between development and production
- Focusing attention on test results at key acquisition decision points.

These are excellent beginnings.

To create incentives for adequate testing, clear direction will first have to be given that defines the timing and expected results of various kinds of testing at each stage in the acquisition. Major steps in this direction have been taken by DOD. It is necessary to then develop a strong testing activity with the stature to its job.

Test results, by themselves, are not foolproof indicators of how good or bad a system will be in operation. However, just prior to a planned full-production commitment, tests should be conducted for the specific purpose of making a "go/no-go" decision. Substantial sums will have been spent on a new program and even larger amounts will be requested for operational system production and deployment. At this point, the system must be subjected to a tough and objective evaluation of its usefulness under expected operating conditions.

Recommendation 9. Withhold agency head approval and congressional commitments for full production and use of new systems until the need has been reconfirmed and the system performance has been tested and evaluated in an environment that closely approximates the expected operational conditions.

(a) Establish in each agency component an operational test and evaluation activity separate from the developer and user organizations.

(b) Continue efforts to strengthen test and evaluation capabilities in the military services with emphasis on:

(1) Tactically oriented test designers

(2) Test personnel with operational and scientific background

(3) Tactical and environmental realism

(4) Setting critical test objectives, evaluation, and reporting.

(c) Establish an agencywide definition of the scope of operational test and evaluation to include:

(1) Assessment of critical performance characteristics of an emerging system to determine usefulness to ultimate users

(2) Joint testing of systems whose missions cross service lines

(3) Two-sided adversary-type testing when needed to provide operational realism

(4) Operational test and evaluation during the system life cycle as changes occur in need assessment, mission goals, and as a result of technical modifications to the system.

Contracting methods and procedures have been used as remedies for acquisition problems found in past programs. This has stimulated a large growth in contracting regulations that have been applied to most programs, whether appropriate or not.

There is widespread dissatisfaction with the voluminous size and detail of contracting regulations. Common complaints are the frequency of change, the ponderous waiver routes required for use of nonstandard clauses, and the practical impossibility of being able to understand and intelligently apply all that is included in them.

The personnel assigned to major system procurement are or should be the best available to the procuring organization. They should not need detailed formula substitutes for judgment. Excessively detailed guidance and requirements to use ineffective contract provisions have been an impediment to major system acquisitions. In this area, there is a great need for personnel to have adequate authority to adapt, modify, innovate, and be held responsible for actions taken.

The problems in contract performance cannot be corrected by contract procedures. The problems are rooted in the actions or inactions in earlier phases of the acquisition process. The cumulative effect of prior recommendations having to do with competing system-level technical approaches, a test demonstration phase, and a strengthened testing activity is intended to provide realistic Government procurement specifications. The result should be simplified contractual arrangements.

Recommendation 10. Use contracting as an important tool of system acquisition, not as a substitute for management of acquisition programs. In so doing:

(a) Set policy guidelines within which experienced personnel may exercise judgment in selectively applying detailed contracting regulations.

(b) Develop simplified contractual arrangements and clauses for use in awarding final development and production contracts for demonstrated systems tested under competitive conditions.

(c) Allow contracting officials to use priced production options if critical test milestones have reduced risk to the point that the remaining development work is relatively straightforward.

Organization, Management, and Personnel

An understandable desire to avoid past mistakes and blunt future criticisms results in an unstable tendency in bureaucracies either to draw all matters up to the highest possible level for decision or to leave critical decisions and information at too low a level. DOD management philosophy, for example, has exhibited wide swings between "centralized" and "decentralized" patterns of decisionmaking. These two approaches generally describe the relative authority of the Office of the Secretary of Defense (OSD) and the military services, but also have meaning within a military service.

DOD recently has attempted to balance the advantages and disadvantages of centralization with a philosophy of "selective decentralization" and "participatory management." This philosophy has given the military services greater responsibility for their acquisition programs. An attempt to find an effective middle ground is proper, but policy and management philosophy must be buttressed by clear statements on the placement of specific decision authority and management responsibility within OSD and the military services.

At present, the responsibility for policymaking and monitoring acquisition programs is split between the technical and business functions at top agency and component head levels. No single office is accountable to the agency head for overall results of acquisition policies.

When new acquisition programs are initiated, procurement must begin using the tools and techniques prescribed by procurement policy and regulations. Such policies and regulations, often intended for more orthodox procurements, have caused problems when applied to advanced technology major systems. Technical and business policies and the people who make them are not closely interrelated. The result has been that procurement methods and contracting techniques do not match the character of technical activity embodied in major system acquisition programs.

On the other hand, early technical activities commit to requirements and actions that prejudice strongly the business structure of any program. With technical needs and considerations occurring first and the business activity second, a vacuum is created in the acquisition process. Issues such as roles and relationships of the Government and industry in defining and developing a system, competitive approach, technical risk, time factors, contracting, and cost should be actively considered from the start.

The split between the technical and business functions also is part of a more widespread pattern of management layering and duplicate staffing that includes agency components where multiple assignments of authority and responsibility also exist.

During the past 15 years, the problem of management layering and excessive staffing has been exhaustively documented but only marginally improved. Its actual impact on the cost of programs is impossible to assess. Whatever the total, the costs are multiplied in industry; contractors who deal with agency staff specialists must create counterparts in their own staffs.

Within an agency component, the acquisition program office is a natural focal point for operating authority and responsibility. The program manager usually is assigned after a major system has been defined and therefore has no role in some of the most important decisions governing execution and success of the program for which he is made responsible. Program managers recently have been given increased authority, but it is difficult to exercise that authority in the current DOD environment. There is too much layering, too much fragmentation of authority and responsibility, and too many coordination points and staff reviews up through the top level.

Recommendation 11. Unify policymaking and monitoring responsibilities for major system acquisitions within each agency and agency component. Responsibilities and authority of unified offices should be to:

(a) Set system acquisition policy.

(b) Monitor results of acquisition policy.

(c) Integrate technical and business management policy for major systems.

(d) Act for the secretary in agency head decision points for each system acquisition program.

(e) Establish a policy for assigning program managers when acquisition programs are initiated.

(f) Insure that key personnel have long-term experience in a variety of Government/industry system acquisition activities and institute a career program to enlarge on that experience.

(g) Minimize management layering, staff reviews, coordinating points, unnecessary procedures, reporting, and paperwork on both the agency and industry side of major system acquisitions.

Recommendation 12. Delegate authority for all technical and program decisions to the operating agency components except for the key agency head decisions of:

(a) Defining and updating the mission need and the goals that an acquisition effort is to achieve.

(b) Approving alternative systems to be committed to system fabrication and demonstration.

(c) Approving the preferred system chosen for final development and limited production.

(d) Approving full production release.

CHAPTER 2

Introduction and Study Approach

INTRODUCTION

Most of today's concern over major system acquisition centers on DOD and its weapon programs. This concern, together with its long experience and numerous programs, makes DOD a natural focus for this report.

As shown in table 1, 141 current system acquisition programs have been identified in DOD with a total estimated cost through completion of nearly $163 billion, of which $93 billion is yet to be programmed and paid for. This cost covers only the direct development and investment costs associated with these systems. The cost of operating and maintaining them could easily double the direct acquisition costs although such costs cannot be easily broken out from operating budgets.

In addition to the billions of dollars channeled through hundreds of programs in DOD, major system acquisition programs are beginning to emerge in other Federal agencies. The practices and experiences of the National Aeronautics and Space Administration (NASA) also are instructive although their major systems are not produced in quantities as large as are most defense systems. The Atomic Energy Commission (AEC) has a long history of weapon and energy source development programs to meet both defense and public needs, but these are difficult to identify and analyze as complete programs because a variety of arrangements between Government and private sector groups is used to conduct the final development, production, and use. AEC often shifts into the role of technical adviser and financial assistant.

Although often not recognized, defined, or conducted as complete system acquisition programs, educational information, power management, waste management, postal sorting, housing, and traffic control systems can be found in the budgets of other Federal agencies. As larger amounts of public funds are channeled into system acquisition programs, Federal acquisition policies will not only influence the success or failure of public programs but also influence the character of the national re-

TABLE 1. SUMMARY OF MAJOR ACQUISITIONS, DEPARTMENT OF DEFENSE (June 30, 1971)

Service	No. of systems	Estimated cost through completion (Millions of dollars)			
		RDT&E	PROC.	MCA	Total
Army	32	5,714.3	21,293.0	906.7	27,914.0
Navy	90	10,384.2	66,651.4	930.8	77,966.4
Air Force	18	13,876.3	42,361.2	539.1	56,776.6
DCA	1	96.4	162.3	.9	259.6
Total	141	30,071.2	130,467.9	2,377.5	162,916.6

Note: RDT&E—Research, development, test, and evaluation appropriation.
PROC.—Procurement appropriations.
MCA—Military construction appropriations.
DCA—Defense Communications Agency.

Source: U.S. Comptroller General, Report B-163058, *Acquisition of Major Weapons Systems*, July 17, 1972, p. 65.

search, technology, and production base and the behavior of private and public organizations engaged in these activities.

Definition of a Major System

A standard definition of a major system, recognized by all Federal agencies, does not exist.[1] The word "system" has become a current day catchall term to connote a concept and anything that fits the concept can be called a "system." For purposes of this report, a major system to be procured by the Federal Government is a collection of interrelated parts that combine to perform a specific function to meet a national need.[2] A system acquisition program is a special kind of problemsolving process that responds to a Federal need by collecting and applying the relevant products of technology. The system that results is of such high cost and complexity that it warrants special management attention.

STUDY APPROACH

The study approach is built on these three points:

- The system acquisition process draws on the base of technology to create systems to meet national needs.
- The process includes a set of basic steps that must be taken by any agency in any acquisition program.
- Different public and private sector institutions are called on to play roles in order to execute each of the basic steps.

The Purpose of Major System Acquisition: Matching Technology to Public Needs

System acquisition programs seek to meet a variety of public needs. Table 2 lists the primary Federal needs for which the Government budgets its resources. There is general agreement that the Government should do something to meet these needs but not on how much it should spend on each or in total—this is the debate over national priorities.

Each primary Federal need is broken down into a hierarchy of supporting needs. Responsibility for meeting primary and supporting needs is delegated to executive branch agencies and their components as their "missions." For example, for DOD to meet the need for national defense, the Army, Navy, Air Force, and Marine Corps have been assigned a variety of strategic and general-purpose warfare missions. Such responsibilities lead them to sponsor new defense systems for air superiority, close air support, fleet air defense, deep interdiction, and others. The C–5A, for example, was the Air Force system developed to meet

TABLE 2. PRIMARY FEDERAL NEEDS

National defense
International affairs and finance
Space research and technology
Agriculture and rural development
Natural resources
Commerce and transportation
Community development and housing
Education and manpower
Health
Income security
Veterans benefits and services

Source: "The Federal Program by Function," *The Budget of the United States, Fiscal 1972.*

[1] DOD has defined a major system acquisition program as follows: ". . . major programs [are those] so designated by the Secretary of Defense/Deputy Secretary of Defense. This description shall consider (1) dollar value (programs which have an estimated RDT&E cost in excess of 50 million dollars, or an estimated production cost in excess of 200 million dollars); (2) national urgency; (3) recommendations by DOD Component Heads or Office of Secretary of Defense (OSD) officials." (U.S. Department of Defense, Directive 5000.1, *Acquisition of Major Defense Systems*, July 13, 1971, p. 1.)

A somewhat similar definition of "a major research and development project" has been given by NASA: "A major research and development project is one which would normally have two or more of the following characteristics: Encompasses design, development, fabrication, test, and operations of advanced aeronautical and space hardware. Requires significant agency resources in terms of manpower, funding, and facilities. Involves important relationships with external organizations, the public, or foreign governments." (National Aeronautics and Space Administration, *Guidelines for Project Planning*, NHB 7121.4, July 1972.)

[2] This definition captures the essence of the definitions used by practitioners of systems engineering. For example:

"A system is a set of objects with relationships between the objects and between their attributes. *Objects* are simply the parts or components of a system. *Attributes* are properties of objects. *Relationships* tie the system together.

"The relationships to be considered in the context of a given set of objects *depend on the problem at hand,* important or interesting relationships being included, trivial or unessential relationships excluded." [Italics supplied.] (Hall, *A Methodology for Systems Engineering*, 1962, p. 60.)

". . . systems exist, or are conceived, to accomplish one or more specific objectives. Both the elements (of the system) and the relationships . . . are carefully selected to achieve a specific purpose." (Hare, *Systems Analysis: A Diagnostic Approach*, 1967, pp. 2, 13.)

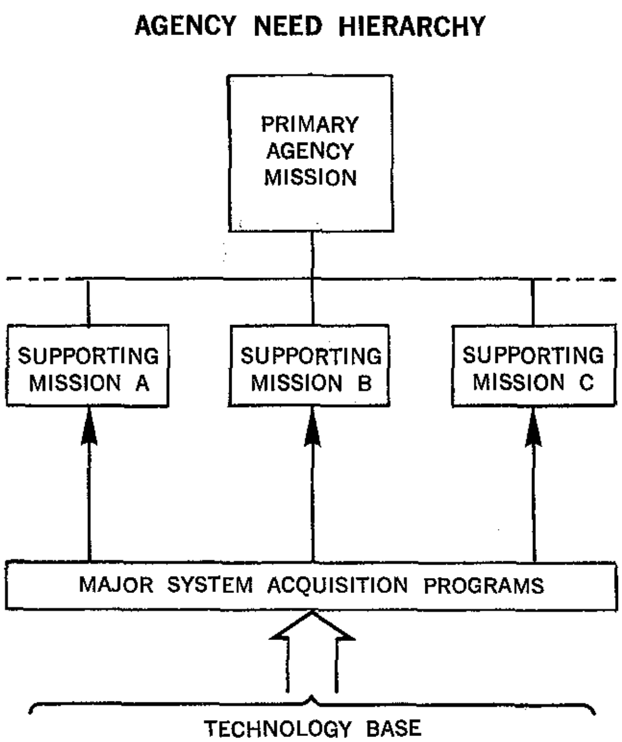
the need for strategic airlift capability, one of the Air Force's mission responsibilities.

The purpose of major system acquisition programs is shown in figure 1. The inability to satisfy a need or a deficiency in one kind of supporting capability can give rise to an organized effort to rectify the problem, a system acquisition program. This is why systems are properly referred to by names that tell the function they are performing, such as a "heavy-lift strategic transport" system, an "urban mass transit" system, or an "automatic traffic control" system. Agencies need the capability to perform assigned functions and acquisition programs produce systems that provide such capabilities.

A Common Structure for the Acquisition Process

Although every system acquisition program draws upon the technology base to create systems to meet a need, each program has its unique features; no two are identical. Differences in time, cost, technical details, management, and contracting approach are explained in the chapters that follow. Despite the differences, certain basic features are common to all programs. Differences in funding, source selection, and program management reflect different ways to accomplish some common basic steps.

THE PURPOSE OF SYSTEM ACQUISITION: MATCHING TECHNOLOGY TO PUBLIC NEEDS



Source: Commission Studies Program.

Figure 1

To provide a thorough and orderly analysis of major system acquisition, a subject that has become enormously complex, this study begins with four basic steps that must be taken in any acquisition program, not with the problems and practices of any one agency or program:[3]

- Establishing needs and goals
- Exploring alternative systems
- Choosing a preferred system
- Implementing the system:
  - Final development
  - Production
  - Deployment and operation.[4]

The study then considers the principal institutions used to execute these steps and examines why and how the visible problems arise from current agency patterns of decisions, information, and motivations.

Figure 2 gives an overview of the study

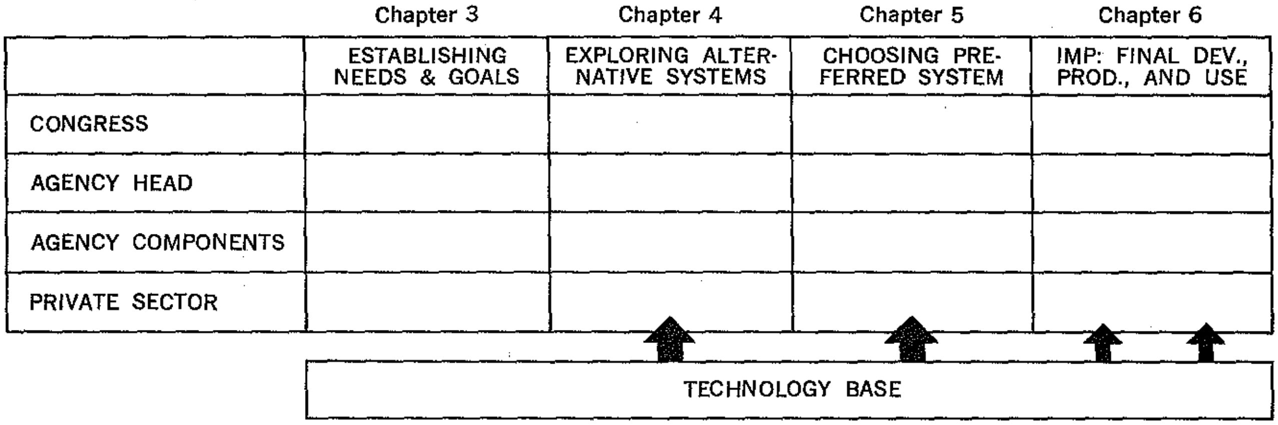
[3] Concern has been expressed that all the program problems and criticisms may be only symptoms of more fundamental difficulties:

"In the past, the Congress and the public have focused on the success or failure of certain specific weapon systems. There has been much dispute and discussion about, for example, whether the cost overrun on a specific weapon system is or is not justified. In these hearings, we hope to get behind the problems of any specific weapon system and examine the acquisition process itself.

"I hope . . . we will be able to begin to understand some of the underlying problems of the weapon system acquisition process, how the system functions, why individuals and institutions behave as they do, what their real incentives are, what sort of reforms in the process will give us a better product." (Opening statement by Senator John C. Stennis, Chairman, Senate Armed Services Committee, *Hearings on Weapon Systems Acquisition Process*, 92d Cong., 1st sess., Dec. 3, 1971, pp. 1–2.)

[4] Other similar lists of steps have been used to describe an organized problemsolving approach for large-scale programs. See, for example, Hall, *A Methodology for Systems Engineering*, 1962, p. 88; Asimow, *Introduction to Design*, 1962; and Research and Policy Committee of the Committee for Economic Development, *Improving Federal Program Performance, A Statement on National Policy*, Sept. 1971. This logic, variously referred to as the "systems approach," "program analysis," and "systematic problemsolving," is being increasingly used as a tool to cope with domestic and global problems such as energy and pollution control. See, for example, Ramo, *Cure for Chaos: Fresh Solutions to Social Problems Through the Systems Approach*, 1969; Forrester, *Urban Dynamics*, 1969; and Danhof, *Government Contracting and Technological Change*, 1968.

STUDY APPROACH & ORGANIZATION



Source: Commission Studies Program.

Figure 2

structure and report organization, the four basic steps in a system acquisition program, and the principal institutions that are involved.

The four steps do not immediately describe all the current complications of major system acquisition. The steps are not a simple sequence; there is feedback, iteration, and many important subsidiary decisions that must be made in order to accomplish each one. Nevertheless, these four steps form a framework for examining issues and options in systems acquisition in an orderly manner. They are all essential, and effective progress depends on what is learned in the prior step.

ESTABLISHING NEEDS AND GOALS

The system acquisition process begins when needs and goals are established by Federal agencies. These needs originate because new jobs must be done or old jobs must be done better through application of advancing technology.

Although a problem (the need) and a solution (the system) must be considered and understood separately, the need and potential solutions are linked by program goals. Goals are the end results to be achieved, that is, the objectives of an acquisition program.

When it has been decided that a need exists, the level of capability desired must be assessed in concert with the desired availability date and the ultimate cost or worth of that capability. These determinations set the goals to be achieved by the acquisition program.

A clear statement of goals is needed to guide the search for the best system and, later, to assess program success.

The first basic step of establishing needs and goals raises several key questions:

- Who identifies the need for a new acquisition program?
- How are these needs coordinated with the responsibilities of different organizations sponsoring acquisition programs?
- How are goals for new programs set and whose views of cost, schedule, and capability goals predominate?
- How are the need and goals reexamined in response to changes that occur as a program proceeds?

EXPLORING ALTERNATIVE SYSTEMS

In commercial dealings, the buyer usually can examine a variety of products that might meet his need and compare their attributes (for example, the size, weight, style, and gas mileage of different automobiles to meet a need for transportation). Federal needs that can be met only by major systems generally do not have counterparts in the commercial marketplace. Therefore, there may be few existing alternative systems for the Government (as a buyer) to examine and compare.

In the acquisition of major systems, if the buyer wants alternative systems from which to choose, he must arrange to have them developed and offered; thus, when the Government wants a choice, it usually must pay not only for the chosen system but also for the creation, development, and presentation of alternative systems that it rejects.

Because creativity and imagination are the catalysts, it is difficult to describe how different systems for meeting a need are originally synthesized. Clearly involved is a blend of technological tools, innovative applications, and operational conditions.

In some cases, due to special capability goals or operating constraints, it may be clear from the outset that the acquisition process should be limited to the development of a single system concept. In other cases, limited testing of the critical pieces of competing concepts may be a worthwhile investment to buy information for that choice. There can be competing system alternatives based on different technical approaches and designs.

Choices of system concepts, technical approaches, and designs are made in every acquisition program; they cannot be avoided and each is important to the success of the program. The decisions do not necessarily follow a distinct sequential pattern. A choice of technology will depend on the ability to match it to the need. A choice of a technical approach will depend on the ability to translate it into a producible engineering design. These decisions progressively narrow the range of final system performance, what it will cost, when it can be available for use, and differences in these factors provide a basis for choosing among competing systems.

Some fundamental questions are:

- How many and what kind of system alternatives are created in current acquisition programs?

- What levels of innovation, new technology, and risk are permitted to enter into competing system candidates from what industry and Government sources?

- What is considered a reasonable expense for evaluating alternatives before commitment to just one system concept, technical approach, or design?

- What organizations and individuals can opt to explore alternative system solutions?

CHOOSING A PREFERRED SYSTEM

The decision to select a preferred system must be made in every acquisition program. The alternative systems considered can be widely different or very similar in unit cost, performance, and delivery date. These are the important factors in determining how well each system matches program goals of mission capability level, total cost, and when the capability is provided.

The choice among systems will be affected by the amount of information purchased to help evaluate each one in light of the need and goals. Research and development buys the information needed to support the choice of system concept, technical approach, and design. However different kinds of information and different levels of confidence are associated with studies, laboratory tests, experimental prototypes, subsystem tests, and full-scale preproduction system tests (the last offering the greatest possibility that the choice among alternatives will be well founded). The key issues are:

- What kind of system choice is offered in an acquisition program and what are the criteria for choosing?

- What kinds of information will be used in choosing a preferred system and at what point in the acquisition process should the choice be made?

IMPLEMENTATION: FINAL DEVELOPMENT, PRODUCTION, AND OPERATION

The scale and complexity of major systems set their acquisition programs apart from other Federal procurements. Usually, the bulk of the resources consumed by an acquisition program goes to production and operation of system end products. To initiate these later phases, critical technical and business issues for source selection and contracting must be faced. The problems of program management stem from the complex engineering interdependencies of subsystems and components and from the variety of laboratories, contractors, and suppliers who contribute to the acquisition effort.

The final development and production phases of an acquisition program remain susceptible to technical uncertainties compounded by changes in needs and goals. If early decisions on technical approach were unsound, the problems of managing the system, the contractor, and the contract are greatly magnified. The fact that, in the final stages of acquisition, one contractor is usually the only realistic source for meeting the Government's need makes matters even more difficult.

The questions that arise in this last phase of acquisition are rooted in how the prior steps have been conducted:

- How well defined is the product when development and production commitments are made?
- What kinds of test and evaluation information are relied on for these commitments?
- What information is used to make program cost estimates and congressional funding commitments? How do these estimates and commitments compare with ultimate system costs and procurement levels?
- How effective are contractual safeguards for the Government in dealing with a single source to meet its need?
- How is acquisition policy established and who monitors the results?

Institutional Considerations

Another primary factor to be considered in any attempt to improve major system acquisition is the role played by different organizations. As the acquisition process proceeds, a wide variety of organizations with different patterns of behavior, motivations, and incentives are called on to make key decisions, supply information for these decisions, and execute them.

Despite the great influence vested interests have over key acquisition decisions, some past acquisition studies tended to focus only on the procedural mechanics of acquisition. Others have dealt solely with organizational behavior. To improve system acquisition, not only procedural impediments but also the roles, objectives, and motivations of participating organizations must be considered.

Congress, executive agencies, agency components (such as the military services), Government laboratories, Federal contract research centers, private sector contractors, technical specialists, and not-for-profit corporations all currently play roles as decisionmakers, information suppliers, and implementers during different steps in the acquisition process.

To analyze and improve major system acquisition, it is necessary to question which institutions should participate in each phase, and in what roles. Not only will the roles of different private and public groups affect the outcome of an acquisition program, but the pattern of assigned public and private responsibilities has a bearing on some broader issues of the structure of Government in the economy and the "free enterprise" character of major system suppliers.[5]

In questioning which public and private sector organizations execute a step or decision, it is natural to ask which others might better perform in these roles. Congressionally chartered quasi-public corporations or Government arsenals for design and production might also be considered to carry out certain acquisition tasks. This part does not deal with these institutional options because these matters are considered elsewhere in the report.[6]

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[5] System acquisition programs and their Government/industry relationships have provoked some observers to note that segments of the defense industry are already on their way toward nationalization, perhaps not by the measure of state ownership but on the basis of state management and control over the companies' products and practices.

A statement by Dr. Murray L. Weidenbaum summarizes this concern: "As I observe the cumulative effect of the close military-industrial relationship, I am struck by the extent to which the Government is taking on the traditional role of the private entrepreneur while the companies are acquiring many of the characteristics of a Government agency or arsenal. Policy changes supposedly designed to increase efficiency must take account of and, I should hope, avoid these unintended side effects." (*Economics of Military Procurement*, hearings before the Subcommittee on Economy in Government, Joint Economic Committee, 90th Cong., 2d sess., Murray L. Weidenbaum, Professor of Economics, Washington University, Nov. 11, 1968, Jan. 16, 1969, p. 63.)

See also:

Adams, *The Military Industrial Complex: A Market Structure Analysis*, paper presented at the Annual Meeting of the American Economic Association, Dec. 27, 1971.

Jewkes, *Public and Private Enterprise*, Lindsay Memorial Lectures given at the University of Keele, 1964, University of Chicago Press.

Galbraith, "The Big Defense Firms are Really Public Firms and Should be Nationalized," *New York Times Magazine*, Nov. 16, 1969.

Melman, "Lockheed: Is It Private Enterprise? Pentagon Controls 95 Percent of Sales," *New York Times*, June 5, 1971.

[6] Particularly in Part A, Chapter 6.

CHAPTER 3

Needs and Goals for New Acquisition Programs

BACKGROUND

Defining a need is a step common to all procurement. This step is especially crucial in major system acquisition programs because it results in the creation of new products to meet the need. Thus, the definition of the need itself greatly influences the kind of systems that will be proposed, designed, and later procured. The initial goals set for a new program can determine the size, cost, and complexity of the system eventually produced.

Current Defense Procedures

In the early 1960's, DOD developed a planning, programming, and budgeting system to improve the allocation of resources by grouping expenditures under national security objectives. Defense need (or "mission") areas include strategic forces, general purpose forces, airlift and sealift forces, and others. These mission areas outline the defense need hierarchy and are used as a frame of reference in the annual posture statement by the Secretary of Defense (see fig. 1).

DOD planning begins with an exchange of information between the Joint Chiefs of Staff (JCS) and the Office of the Secretary of Defense (OSD) on national defense policy, strategy, security objectives, and the military forces the JCS believes are necessary to achieve them.[1] OSD does not present guidance in terms of capabilities for supporting defense mission needs (such as amphibious assault, strategic airlift, or fleet air defense). These mission responsibilities are delegated to the military services and generally have been shared ever since the "Key West Agreement" provided for "primary" and "collateral" mission responsibilities.[2]

OSD does not allocate the total defense budget to a set of specific defense missions. Instead, each service is allocated a share of the budget, with an occasional restriction on how much can be spent in a special mission area. Within these fiscal limits, each service plans its own forces, systems, manpower, cost, and materiel requirements,[3] all projected for a five-year period. All of these plans must be within the total dollar limits established by the Secretary for each service.

The plans of all the services, limited by allocated funds, are contained in a JCS document[4] that presents the Joint Chiefs' best judgment on needed forces and weapons, and discusses the risk being run by reducing forces (and expenditures) from a "capability first"

[1] The first document in the annual planning, programming, and budgeting cycle is issued by the JCS (the *Joint Strategic Objectives Plan* (JSOP), vol. 1, Strategy). It outlines the strategic and force judgments of JCS for attaining national security objectives. The Secretary of Defense then issues his "Policy and Planning Guidance" using information from JCS, the National Security Council, and the President's defense policy. Policy and planning guidance, in general, deals with the goals and strategy for meeting top-level needs for national defense. It outlines the national security objectives the United States should be prepared to meet, the expected number and kind of conflicts, and other pertinent elements of defense strategy.

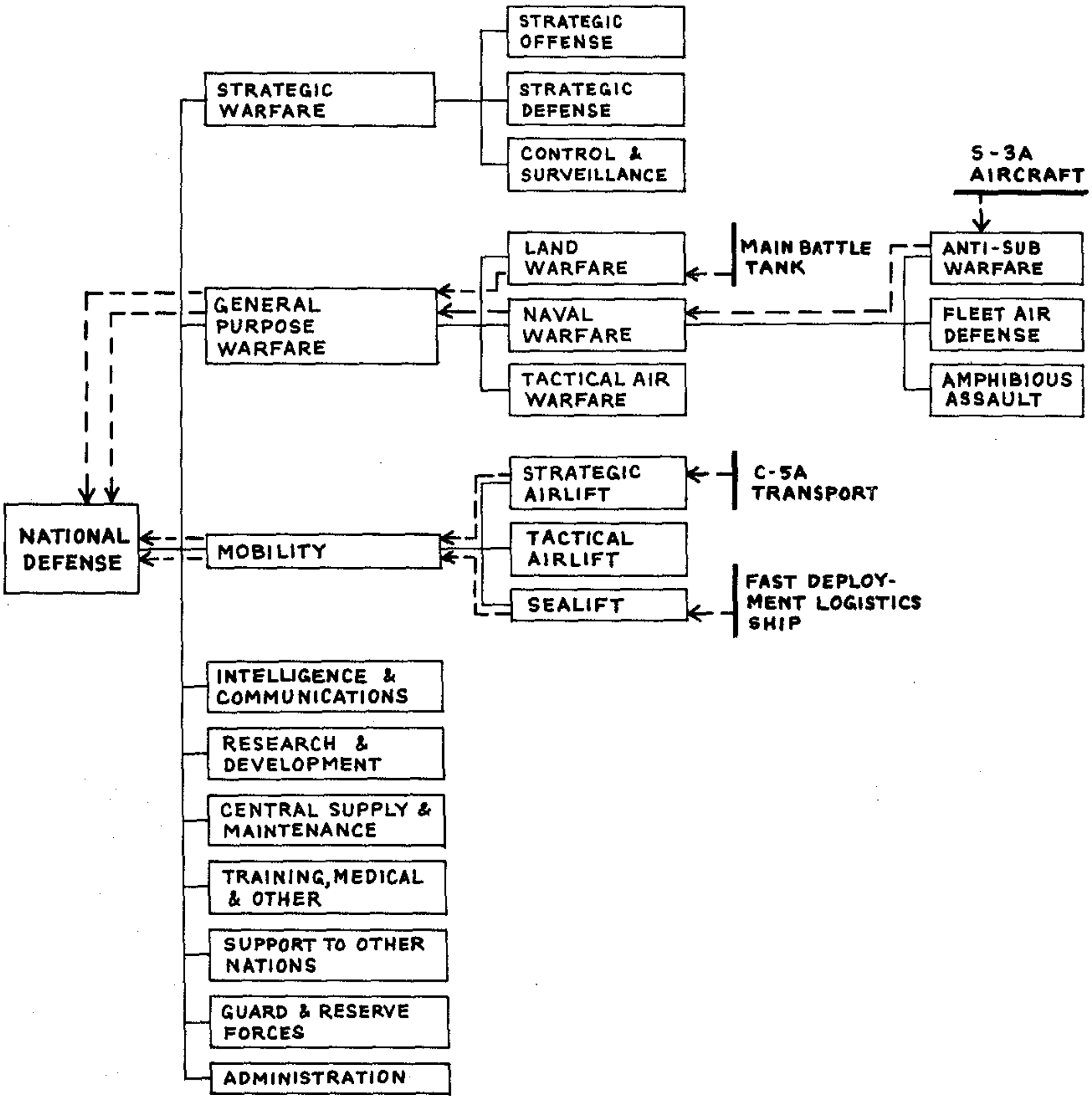
Using the Secretary's guidance without dollar limitations, JCS describes those military forces (and major systems for those forces) they feel can execute defense strategy "within the criteria of reasonable attainability and prudent risks." (JSOP, vol. II, Analyses and Force Tabulations).

[2] The original attempt to define the roles and missions of the services under a civilian Secretary of Defense came in 1948. See "Functions of the Armed Forces and the Joint Chiefs of Staff," attachment to Office of the Secretary of Defense Press Release No. 38–48, *Secretary Forrestal Announces Results of Key West Conference*, Mar. 26, 1948.

[3] The Program Objectives Memoranda (POMs).

[4] The Joint Forces Memorandum (JFM).

DEFENSE MISSION NEED HIERARCHY WITH SOME SPECIFIC RELATED SYSTEMS



Source: Figure abstracted from statement by the Secretary of Defense on the Fiscal 1973 defense budget.

Figure 1

level proposed before budget limits were imposed. Forces and systems (both in inventory and planned) are collected and grouped under major mission headings,[5] presenting the kinds and number of weapon systems being sponsored by all the services. The systems proposed by the services for inclusion in these plans usually are in the later stages of development so that the number to be procured and their costs both have been specified as a result of needs expressed earlier by each service to meet its own mission responsibilities.

Current DOD acquisition policy delegates the first decisions on needs and the responsibility for defining the systems to each military service.[6]

The first statement of a need can originate within any of the organizations in a military service or in conjunction with industry through unsolicited proposals. In the Army and Air Force, first need statements that start an acquisition program are called Required Operational Capability documents (ROCs).[7] The Navy initiates early acquisition efforts through Tentative Specific Operational Requirements (TSORs) or Proposed Technical Approaches (PTAs)[8] written to respond to a permanent set of Navy mission statements that are regularly updated.[9]

ROCs, PTAs, and TSORs are the current equivalent of need statements for new acquisition programs. Once coordinated with the appropriate echelons of the service and approved by headquarters, technical activity begins to be sponsored by the development commands. Congress finances this work through the approximately 400 program elements and 4,000 projects in the research, development, test, and evaluation (RDT&E) budget but, like the OSD, does not directly play any role in establishing the need statements for new system acquisition efforts.

PROBLEM DISCUSSION

There are three principal problems in the way needs and goals for major system acquisition programs are currently established.

First: The statement of need does not clearly separate the problem from the solution. Early acquisition plans concentrate on a "needed" new system and a preferred system approach with inadequate attention to why any new capability is needed at all and what that capability is worth. One of the reasons new systems have been more and more complex and costly is that current acquisition procedures tend to say "this is what we need" from the outset, in accommodating a host of stipulations on system characteristics and performance.

Second: Needs currently are defined by each military service with little or no formal agencywide coordination. Needs are subject to individual service views of priorities, weighting of goals, and interservice rivalry. This contributes to unplanned duplication in system capabilities and the multimission character of expensive new systems.

Third: Congress does not have oversight into the need for new acquisition programs.

[5] Strategic Forces, Land Forces, Tactical Air Forces, Naval Forces, Mobility Forces.

[6] "The DOD components [military services and other defense agencies] are responsible for identifying needs . . ." Department of Defense, Directive 5000.1, *Acquisition of Major Defense Systems*, July 13, 1971, p. 2.

[7] For example, "The first step in the development of a system must be the establishment of a Required Operational Capability (ROC). A ROC *may originate anywhere in the Army*—at one of the schools or centers, in one of the operational commands, in the Army Materiel Command (AMC), Combat Developments Command (CDC), Army staff, Secretariat, *or the idea might originate with industry*." [Italics added.] AR 1000–1, *Basic Policies for Systems Acquisition by the Department of the Army*, June 30, 1972, p. 1.

The Air Force states that, "An operational requirement *may be recognized, stated, and forwarded* as outlined herein *by any echelon of the Air Force* or Department of Defense." [Italics added.] AF Regulation 57–1, *Policies, Responsibilities, and Procedures for Obtaining New and Improved Operational Capabilities*, Aug. 17, 1971, p. 3.

[8] "The Proposed Technical Approaches, prepared by the Naval Material Commands (NMC) and Bureaus and Offices of the Navy Department, are the formal documents by which technical approaches to achieve a particular capability are presented. PTAs *may be submitted as unsolicited proposals in response to the broad requirements statements* in a General Operational Requirement (GOR) *to call attention to possibilities for a naval warfare system* resulting from advancing technology, but are the *required (solicited) responses to Tentative Specific Operational Requirements* (TSOR) in which alternative approaches *to attain the particular capability* desired are recommended. PTAs provide a major source of the financial and technical information which is necessary during *the early concept formulation phases* in order for the CNO to determine whether to *commence development programs*." [Italics added.] OPNAV Instruction 3910.8B, *Proposed Technical Approaches (PTA)*, Dec. 8, 1967, p. 1.

[9] The Navy maintains a broadly defined set of General Operational Requirements (GORs) that are very close to a statement of mission needs and goals for the major Navy missions. These documents, however, are maintained on a continuous updated basis and do not themselves initiate, define, or set limits on new acquisition programs.

Although Congress can see the defense program in terms of missions and systems already chosen to perform them, it does not review the start of the acquisition process, the establishment of needs and goals that precedes the search for alternatives. Issues on mission need first emerge for congressional review after the search for alternative systems essentially has been completed and a specific system is proposed for funding in the final stages of development in preparation for production. This makes control of agency budgets and allocation of resources to meet national needs difficult at best.

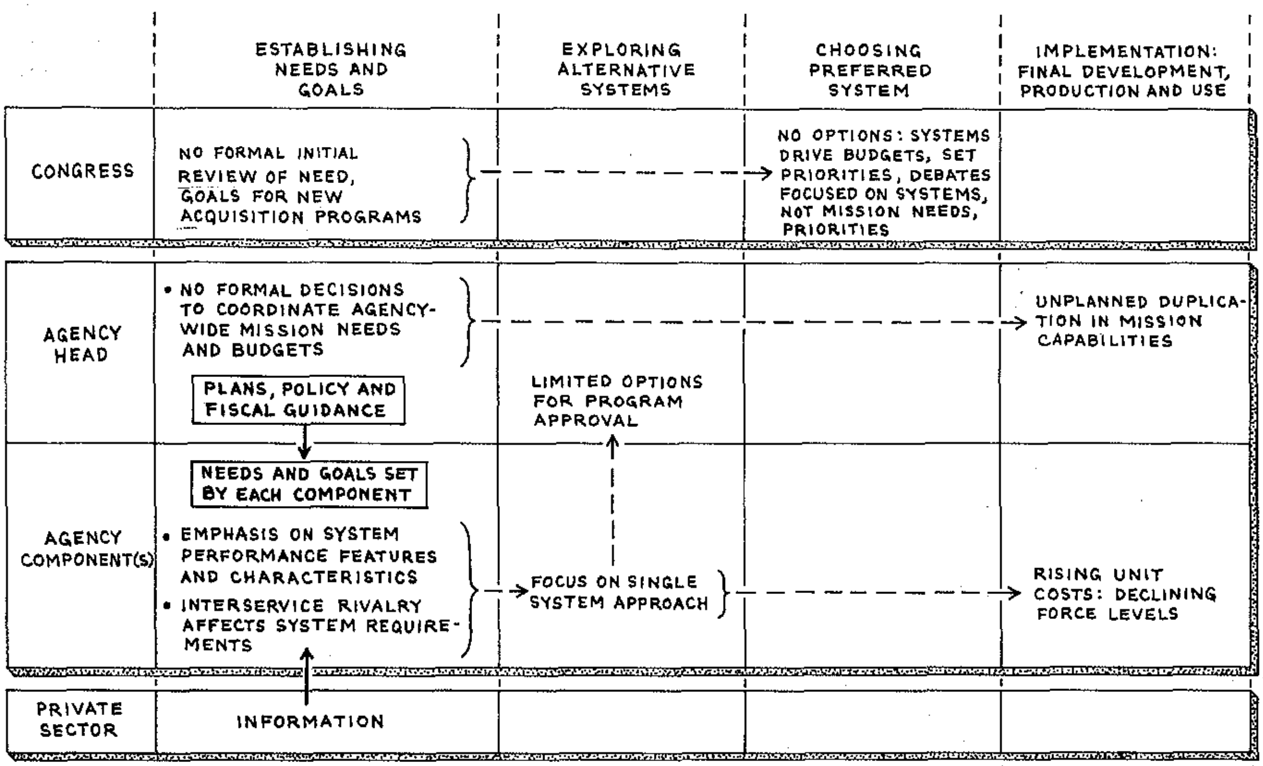
These problems and the difficulties they cause in the acquisition process are summarized in figure 2.

Statements of Needs and Goals

The initial statements of need currently used by the military services to start acquisition programs do not separate operational need from system solution and do not present program goals independently of a particular system. The titles of statements of need (the TSORs and PTAs of the Navy and the ROCs of the Army and Air Force) imply that they are statements of the operational problem to be solved, which they are in part, but they also move directly into a preferred system product in considerable detail. For example, one statement of a mission need called not only for a new *manned aircraft* but also called out:

CURRENT PATTERN OF ESTABLISHING NEEDS AND GOALS FOR NEW ACQUISITION EFFORTS

PROBLEMS AND IMPLICATIONS



Source: Commission Studies Program.

Figure 2

Takeoff and landing distances
Combat radius and combat profile with weapon loads and energy gains for maneuvering
Sea-level speed
Maximum speed
Ferry range
Eight separate design point performance specifications
Thrust-to-weight ratio
Structural load factors
Fire control systems for specified missile types, guns, and other functions
Navigational system accuracy limits and number of preset checkpoints
Guns better than those in operation
External fuel tank capacity
Month of latest IOC
Other system performance characteristics.

Another "statement of need" specified:

Number of engines
Speeds at different altitudes
Maneuvering performance
Weight
Armament
Radius of action and combat profiles
Takeoff and landing distances
Structural load factor.

CONSTRAINTS ON NEW SYSTEMS

Needs are expressed in terms of a product rather than a mission function to be performed because preliminary design studies of a system often precede the initial requirement for operational capability. In an effort to get the inside track on new military business, contractors regularly market their proposed products to the development and operational commands that write new requirements. "Requirements" set forth in the first statement of need often reflect proposals and promises made by one or several contractors.

In addition to the problem statement, some practical restrictions on system solutions may have to be stated, but they need not be the kind listed above. If an aircraft system is to be proposed to meet a Navy need, for example, the designer must be told to make it small enough to fit the hangar deck and elevators of aircraft carriers. Examples of appropriate limitations on systems to meet the need to attack ground targets from the air might specify:

- Kind of targets (radar installations, bridges, ships, tanks, etc.), their locations, and how thoroughly they should be disabled
- Environmental conditions in which the system must operate, including the operating terrains, nature and intensity of enemy defenses, enemy countermeasures near the target, expected enemy tactics, and weather conditions
- Tactics that would be used by forces using the system, such as number of raids in a given time period, preferred assault method, and electronic countermeasure accompaniment
- Capabilities of the organization that will use the system (such as the technical competence of combat and support personnel) and interface with other systems they will be using.

Note that none of these conditions say what the system should look like (for example, a twin-engine turbojet aircraft) or state aircraft performance requirements (such as takeoff distance, cruise speed, dash speed, or weight).[10]

All of the stipulations typically included in the military's "need" statement fairly well outline the preferred system to meet the mission need. The focus is on the product rather than its purpose. The explanation for increasingly large, expensive new systems comes in part from the fact that these are the kind of systems "needed" from the outset of an acquisition effort rather than systems created within the confines of mission capability, cost, and schedule goals.

Needs that are set in terms of the system to be built can deny, delay, or overextend the application of new technical approaches. As found in a study of new system developments in DOD, "the interaction of scientific and technological knowledge is stimulated by, and is most productive for, weapon system de-

[10] In fact, these boundary conditions were being made for a report on tactical missiles, not aircraft. Boundary conditions need not specify the product. U.S. Comptroller General, Report B–160212, *Actions Needed to Reduce the Proliferation of Tactical Air-to-Ground Missiles*, Dec. 31, 1970, pp. 75–76.

velopment in a problem-oriented environment." [11] However, a program that is formulated and pursued with attention focused on a particular system can lock-in on a technical approach that is far too ambitious.

CONSTRAINTS ON PROGRAM PURPOSE AND GOALS

Questions of national policies, priorities, and capabilities must precede and be separated from the search for a particular kind of system. Needs that specify a collection of system characteristics do not lend themselves to such questions because the system performance, cost, and availability are predetermined within a limited range, reflecting implied answers to mission needs and goals. The level of mission capability, the cost to achieve that capability, and the time it becomes available are three principal bases for setting goals for an acquisition program. An effort to gain increased capability for a supporting mission has implications for the higher missions. Increased fleet air defense capability may imply we will use the fleet in certain ways that may or may not be consonant with defense policy or strategy.

Depending on the circumstances of the need, one or several goals may be particularly critical if the program is to be considered successful. There are few, if any, needs that should be met at any cost, but there are needs that are more sensitive to capability or schedule than to the cost of meeting them. Cost, schedule, and capability, considered individually, do not necessarily indicate whether the acquisition program is a success or a failure. Different emphasis may be given to cost, schedule, and capability goals to measure a "successful" program. A successful program is one that best matches the relative importance of the goals it seeks to achieve.[12]

[11] U.S. Department of Defense, Office of the Director of Defense Research and Engineering, *Project HINDSIGHT, Final Report*, Oct. 1969, p. iv. By contrast, the other environment can be described as "product-oriented," not "problem-oriented."

[12] For example, the early ballistic missile programs incurred large cost overruns and their initial operational performance was deficient. Yet, these early programs were not counted as failures but, rather, successes because the goals perceived during the "missile gap" era put overriding emphasis on early deployment of some kind of deterrent capability. A RAND Corporation study of the ICBM programs characterized them as perhaps a case in point "where an immediate demonstration force is needed whether or not it works." Klein, Glennan, and Schubert, *The Role of Prototypes in Development*, June 10, 1963.

Balancing capability against cost goals can lead to a variety of answers to the question "How much is enough?" from operating organizations that must maintain operational capability, or agency heads and Congress that must set limits on available resources. The limit on available resources and what has been spent in the past for a particular capability are generally good starting points for reconciling cost with schedule and capability goals. Goals set the tone of the program and should not be implied by a "needed" system.

Because an acquisition program should explore alternative systems and balance their unit cost, performance, and schedule, it is especially important for those executing the program to know the mission need and goals and the relative importance of cost, time, and capability in order to guide the search for a system.

A variety of systems, each with different performance characteristics and unit costs, might be bought to achieve the same level of mission capability at the same total cost. At the very outset, it is difficult to set goals based on a particular system. To set a unit cost goal for an airplane, for example, someone must know what the technical and performance characteristics of the airplane will be and, consequently, how many will be needed for a level of mission capability. This is impossible to know before a system is designed in one way or another. If programs start with a unit cost goal, then they have already passed into the choice of a preferred system.

SEPARATING THE PRODUCT FROM ITS PURPOSE

Setting needs and goals in terms of a product limits the effectiveness of a search for information and alternatives. The search may lead to a revision of program goals. A lower level of mission capability, a higher program cost, or a delayed date for meeting the need may have to be considered if no alternative system can be found to meet the initially stated conditions. Need and goals can change due to external conditions, quite apart from a program and its search for the best system. When needs are susceptible to change, as defense needs are, regular updating must be made if an acquisition program is to retain within it sufficiently wide system options to accommodate such changes.

A decision to initiate an acquisition program often can be prompted by the recognition of new technological opportunities. New system ideas and approaches created in the technology base can first draw agency attention to performing functions it has not done or needed before. Even when a technological breakthrough provides the initial impetus for a new program, however, the mission need to be met should be questioned. If the combination of potential opportunities, agency priorities, and available resources warrant a new program, the system idea should be permitted to evolve freely within program limits based on mission goals, not premature product specifications.

The need should be separated from any particular system, and goals should be defined independently of the performance, cost, and schedule characteristics of any particular system. Decisions on mission needs and goals set acceptable limits on the acquisition program. Within these limits, alternative systems, performance requirements, and unit costs should be explored. The next step of an acquisition process—the exploration of alternative solutions—requires that these things be specified:

- A statement of the problem to be solved or the deficiency in mission capability, including those conditions that have created the problem or deficiency
- The goals to be achieved by the acquisition program and their relative importance, including level of mission capability, program cost, and when the capability should be available
- The boundary conditions that must be met by any system, including constraints on physical size, operating conditions, tactics, and the talents of the users.

Coordinating Needs and Goals

Figure 3 shows the most recent representations of the missions each service is performing and toward which its major system acquisition programs are directed. For comparison, it also shows the DOD mission need hierarchy used in the most recent budget preparations.

The Navy's mission needs are based on the fewest number of first-order capabilities: strike warfare; antisubmarine and undersea warfare; command support; and operational support. There are 29 supporting missions toward which their TSORs and PTAs are written, such as sea-based strategic systems and amphibious assault.[13]

The Army directs all operational and materiel objectives and requirements toward 18 categories of supporting missions, including amphibious and airmobile operations. The Air Force Systems Command names 14 missions, including close air support and interdiction.

Comparison of mission need hierarchies in figure 3 indicates the difficulty in coordinating the needs for new acquisition programs between services and with the broader DOD planning and budgeting missions.

INTERSERVICE RIVALRY

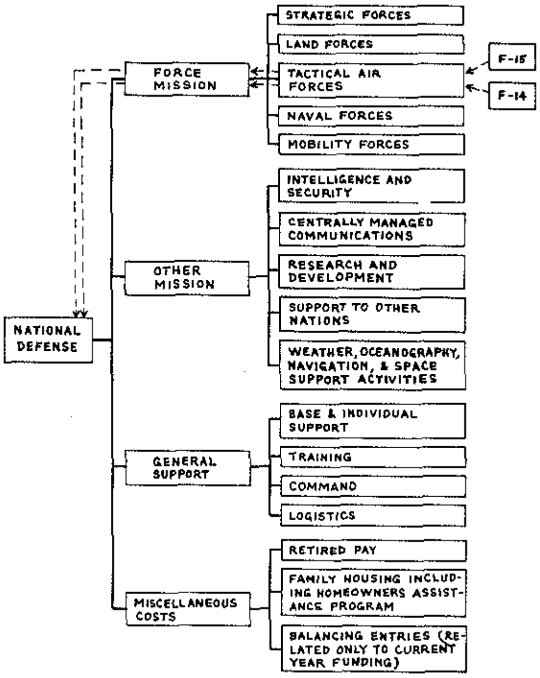
Because needs and goals for new programs are decided independently by each service, the chance that uncoordinated programs might result in unnecessary or overlapping capabilities is increased. It also opens the door for the longstanding defense problem of roles and missions competition among the services, which can strongly affect the size, shape, and cost of new weapon systems.

Although a mission "need" document may originate with lower-level technical or operational commands, a review occurs at the service headquarters before the formal statement of need is issued. There is much interest and speculation concerning the efforts of other military services to meet related mission needs, especially if mission responsibilities are not separated clearly.

The latest fighter aircraft programs of two services, the Air Force F–15 "Eagle" and

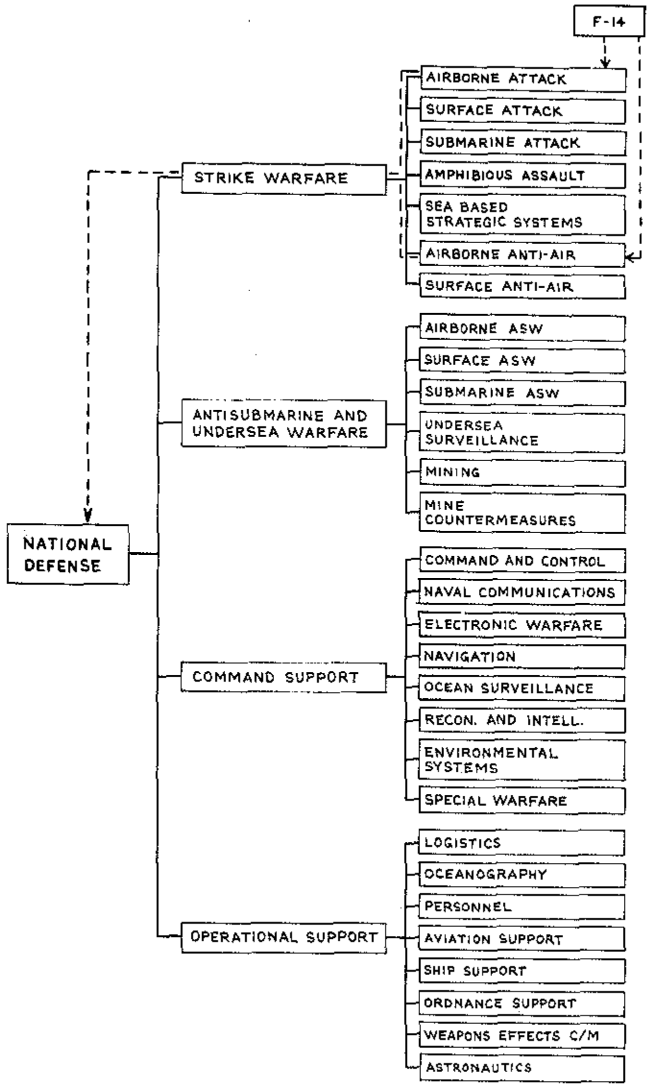
[13] At the time of this study, both the Army and Navy were in the process of revising the relationship between their missions and early acquisition planning documents. The Navy was redefining and restructuring its missions underneath four basic ones: strategic deterrence; projection of power ashore; sea control; and mission support. The Army expected to issue a new combat development objectives guide in 1973.

DOD FISCAL GUIDANCE CATEGORIES



SOURCE:
MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS AND DIRECTORS OF DEFENSE AGENCIES, SUBJ.: DEFINITION OF FISCAL GUIDANCE CATEGORIES BY PROGRAM ELEMENT, OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE, SYSTEMS ANALYSIS, MAR. 10, 1972.

NAVY



SOURCE: OPNAV INSTRUCTION 3910.9D, GENERAL OPERATIONAL REQUIREMENTS (GORs) FOR NAVY RESEARCH AND DEVELOPMENT, OFFICE OF THE CHIEF OF NAVAL OPERATIONS, MAR. 3, 1971.

Figure 3

MISSION HIERARCHIES

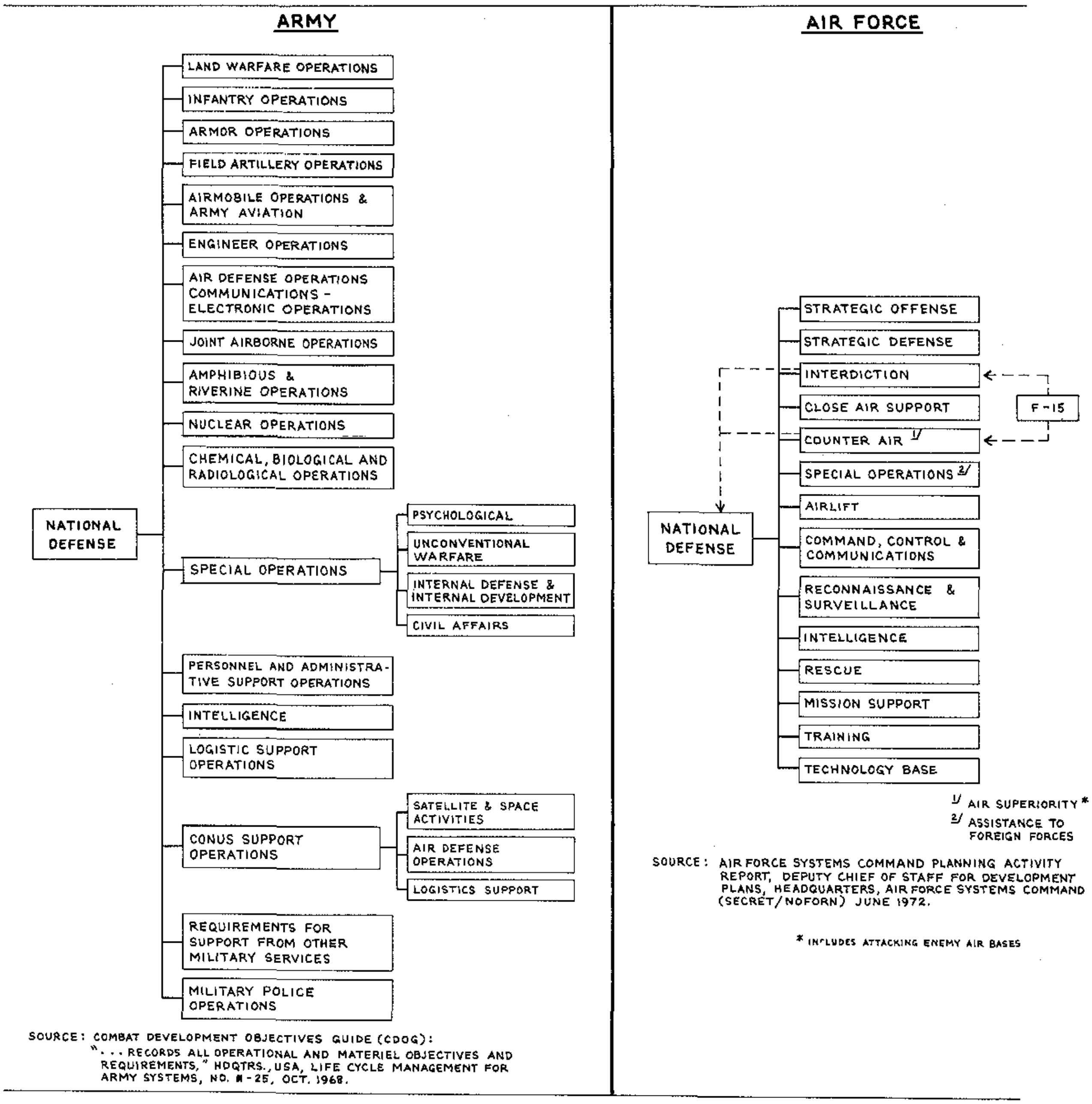


Figure 3 (continued)

Navy F–14 "Tomcat," illustrate the difficulty in coordinating needs for new acquisition programs when mission objectives are not clearly defined or separated. They also demonstrate how systems can be affected by bureaucratic sparring over roles and missions, a two-year contest in this case.[14]

From the DOD viewpoint, both the F–14 and F–15 are considered as units of the tactical air forces as shown in figure 3. But from the viewpoint of the services, the F–15 is intended to meet the Air Force mission needs for counter air (air superiority) and interdiction capability; the F–14 is intended to meet Navy mission needs for airborne attack (air superiority and strike attack) and airborne anti-air (fleet air defense).

The F–15 was originally conceived by the Air Force for air-to-air combat and was to be available by around 1970. It was to weigh 20,000 to 30,000 pounds and be more maneuverable than the F–4 "Phantom" fighter. Future needs for the deep interdiction mission (and standoff air-to-air missile capability) were to be met by a heavier follow-on aircraft to be operational around 1975.

The Navy has mission responsibility for overland air operations during amphibious assault, a need that could be met by a high-performance aircraft akin to the F–15, as that aircraft was originally described by the Air Force.[15] In addition, the Navy could use a high-performance fighter to replace its aging F–8.

There arose the possibility that because the aircraft could be similar, the better system might be used for both the Air Force and Navy missions. Under these conditions it was natural for the Navy to consider whether the Air Force, by initiating its F–15 program, would put itself in a position to manage a biservice fighter for itself and the Navy.[16]

The Navy put forward its own fighter aircraft proposal. The Naval Air Systems Command laid out plans for a fighter/attack aircraft that was to become the F–14 and the issue of commonality was raised to the OSD level. The Secretary of Defense directed that a study be made of making the Navy and Air Force aircraft a common airplane. The debate was eventually concluded; each service would continue to pursue its own fighter aircraft.

Following the extended period of debate, the original Air Force plans for separate smaller and larger aircraft by 1970 and 1975 were invalidated. To meet both mission needs (air superiority and interdiction), some features of both aircraft were merged into what has become the F–15. When the F–111B program collapsed in 1968, the Navy's aircraft was changed to meet the fleet air defense mission need as well as its original air superiority mission. As a result, the F–14, capable of carrying long-range missiles on combat air patrol, grew larger and more expensive than the fighter envisioned for the air superiority mission.

The main point is not that there should have been one or two airplanes but that it is difficult to coordinate mission capabilities, service assignments, and the need for new programs when these issues arise after new systems are defined and proposed.[17]

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[14] Perhaps the most carefully analyzed contest between services and their systems was for the strategic retaliation mission. It was a mission dominated by the Air Force during World War II when bomber aircraft and conventional weapons were used to perform this mission over Germany. The Air Force sponsored several long-range missiles (Snark, Navaho, and Atlas) during the 1940's, and, later, the intermediate-range Thor.

At the same time, the Army was pursuing ballistic missiles to meet its own land combat mission assignments with the understanding that missiles were just another form of artillery. The Army's Jupiter and the Air Force's Thor missiles converged on the strategic offense mission. How far did an artillery shell (or a missile) have to fly before it graduated from a battlefield to a strategic weapon? The weapon systems and missions were not clearly coordinated.

The struggle for these intermediate-range ballistic missiles and the strategic role was further complicated by the Navy's entrance with the fleet ballistic missile (FBM) system just as the Air Force was winning the Thor-Jupiter battle.

The net result is that today both the Air Force and Navy perform this strategic offense mission with the most expensive weapons in the defense inventory, land-based and sea-based ballistic missiles. Further, the manned bomber remains in the role of strategic retaliation. Today, the new B–1 bomber is in an advanced stage of development.

See in particular, *Organization and Management of Missile Programs*, H. Rept. 1121, Committee on Government Operations, Sept. 2, 1959.

See also H. Rept. 178, *Satellite Communications Military-Civil Roles and Relationships*, Committee on Government Operations, Mar. 17, 1965.

[15] A specialized air superiority aircraft would not compete for funding with the Navy's F–111B fleet air defense fighter which was still nominally a live and going program.

[16] This was done in the F–4 and F–111 fighters. The Navy had managed the biservice F–4; the Air Force was the biservice manager for the F–111 program.

[17] The Navy has a problem in coordinating roles, missions, and systems among its own organizations. An internal study of Navy shipbuilding problems listed as the number one policy issue the fact that ship missions and their operational requirements are generally ill-defined. One large Navy frigate, for example, can be designated to meet several mission needs. Many major systems may all be mounted on the same hull platform. Just as defense missions are assigned to the services, these different Navy mission systems are

Program needs and goals should be questioned on an agencywide basis to assure that unplanned overlap in capability does not occur. Former Deputy Secretary of Defense Packard noted that the divisionary forces that pressure the decisions on what programs to undertake are numerous and powerful. He said that there was competition between the Army, Navy, Air Force, and Marine Corps and frequently, between parts of a service for the allocation of overall Department funds and competition over roles and missions.[18]

A comprehensive review of defense missions and needs for new acquisition programs on an agencywide basis initially would question whether service rivalry and the overlap in roles and capabilities of the military services could be used to find better systems to meet defense needs. If competition to meet an agency mission need is to exist, it should be overt and purposeful.

DOD's Area Coordinating Papers (ACPs) represent the closest current attempt to coordinate systems and programs within mission areas. Although they are intended only to coordinate information and are not formal decisionmaking documents, some features of these papers are examples of what mission need statements should be like to initiate new acquisition programs. There are a total of 43 ACPs planned, each of which is intended to oversee several individual system development efforts within a broad mission area.[19] Most importantly, the ACPs are also intended to organize specific military needs, all the systems related to meeting those needs, and interservice relationships.[20]

ACPs in their current state, however, are not adequate for use as agency mission need statements because they are relatively new and not yet coordinated into a consistent hierarchy of needs separate from product classes. Their further evolution into decision documents for agencywide coordination of new acquisition programs should provide at least a groundwork for recommendations made here.

Resource Allocations and Congressional Controls

In DOD, cost growth, a lack of system options, and rising unit costs for individual systems have resulted in major, unplanned revisions in the size and character of military forces. Deviations in cost and force level have grown to disturbing proportions. The estimated cost of 77 acquisition programs has grown 31 percent ($28.7 billion) over original planning estimates.

In the face of such cost increases, another $11.7 billion worth of cost growth was avoided only because of cutbacks in planned systems, procurement quantities, and planned force levels.[21] This means fewer systems and less than planned for capability. To some observers, major system acquisition programs, collectively, appear to be out of control. The Senate Armed Services Committee noted that current weapon development and procurement policies either point the way to inadequate forces for defense, burdensome increases in defense spending, or to both of these unacceptable alternatives.[22] It is vitally important that monies going to new Federal acquisition programs be controlled and coordinated before resources are committed and that unanticipated deviations be reduced.

assigned to different Navy groups. Rivalry for dollars and influence affect the total ship system depending on the relative bureaucratic success of the several contributing systems commands. The results are strikingly similar to the interservice problems, including "the fragmentation of ship planning and designing among competing specialists in architecture, command and control and weaponry . . ." and "the dispersion of shipbuilding funds into jealously defended bastions, fostering parochial attitudes and leading to destructive competition." (Memorandum for the Chief of Naval Operations, Subject: Shipbuilding, Office of the Assistant Secretary of Defense (Installations and Logistics), June 4, 1971, p. 5–6.)

If the Navy chose to regard the hull and support systems more as a platform for ship-mounted systems, this would lead to a more modularized ship with simplified integration, although the task will still be complex and important. Short of this, an alternative action could be to design smaller, single-purpose (one mission) ships. Without either of these actions, there is the alternative of creating a single organization to oversee all the Navy organizations contributing systems to a multimission ship, including the hull and support systems to be designed and optimized along with all the rest.

[18] U.S. Congress, House, Committee on Appropriations, *Department of Defense Appropriations for 1973. Hearings* before the Subcommittee of the Committee on Appropriations, House of Representatives. 92d Cong., 2d sess., 1972. Washington, Pt. 3, p. 211.

[19] U.S. Department of Defense, Office of the Director of Defense Research and Engineering, *Relationships of ACPs, TCPs, DCPs, PMs,* Dec. 28, 1971, p. 1.

[20] U.S. Department of Defense, Office of the Director of Defense Research and Engineering, *Management of the RDT&E Program and Major Systems Acquisition,* n.d., p. 1.

[21] U.S. Comptroller General, Report B–163058, *Acquisition of Major Weapon Systems, Department of Defense,* July 17, 1972, p. 2.

[22] U.S. Congress, Senate, Armed Services Committee, *1972 Defense Authorization Report,* S. Rept. 92–359, 1971, p. 19.

CONTROLLING RESOURCE ALLOCATIONS

Budget allocations from the Secretary of Defense divide funds among the military services rather than among defense mission needs. This has been a longstanding concern to defense planners. Although these service limits assure some degree of control over total expenditures, they do not effectively control the use of these funds by end purpose. Such service allocations led a former Chairman of the Joint Chiefs of Staff to comment that we did not know what kind and how much defense we were buying with any given budget.[23] A more recent critic commented:

> None of the reforms that [former Deputy Secretary of Defense] Packard has instituted will mean anything unless . . . more control is exercised over how the services allocate their funds. If we reduce the costs of acquiring a weapon, but decide to buy one ill-designed for a specific mission, or one well-designed for a superfluous mission, or if we buy three different weapons where one may suffice, we have wasted money.
>
> Whenever each of the services is permitted to allocate its funds in ways it sees fit, the overall outcome is usually duplication, gold-plating and an unbalanced defense posture. What is good for the Army, Navy, and Air Force, separately, is not necessarily good for the Defense Department as a whole.[24]

Resource allocation problems are not alleviated by congressional review of agency budgets and programs. About half of the funds spent on defense do not fall in a budget category having a clear "end use" in terms of defense capabilities. Examples of this include "research and development" and "training, medical and other general personnel activities" which collectively consume $24.2 billion of the total planned fiscal 1973 budget. Of the remainder, even major systems that are associated with distinct mission categories (such as tactical air forces), give only a general grasp of the purpose for which systems in these forces are being procured.

Effective budget adjustments cannot be achieved by eliminating specific weapons that are the most obvious protuberances in the defense budget, like the funding for a B–1 bomber, an F–14 fighter, or a SAM–D missile system because the capabilities they are contributing must be viewed as part of the whole defense program. Such cuts may be too insensitive to the net effect on defense posture, policy, and capabilities.

Nor will arbitrary percentage cuts in parts of the defense budget, as it is currently structured, insure that defense needs and other priority needs are being met. These cuts will only affect the budgets of the services or activities, not defense capabilities. For example, a member of the House Armed Services Committee said that:

> One of the few cuts made in this year's procurement budget was a five percent reduction in the R.T.D. and E. section recommended by the subcommittee. (Even this five percent reduction leaves the R.T.D. and E. budget $300 million above that of last year.) I am informed that at no point did anyone rationally discuss the impact such a cut would have on the Defense Department. Rather what has happened was that someone suggested a four percent cut in the figure—giving no justification for doing so—and yielded instead to a colleague who urged "rounding" it to five percent.[25]

Conversely, success in meeting domestic needs cannot be insured or measured by the large amounts of money poured into an agency or its programs. Establishing mission needs and goals for new programs is the important control point, regardless of agency missions.

REVIEW OF PROGRAM NEEDS AND GOALS

Congress does not currently review the start of new acquisition programs or examine program goals—the kind of capability being sought, when, and at what price.

Budget reviews, authorizations, and appropriations are all primarily based on products, activities, and the military services, not de-

[23] William W. Kaufman, *The McNamara Strategy*, 1964, pp. 28–29.

[24] Art, "Why We Overspend and Underaccomplish," *Foreign Policy*, No. 6, spring 1972, pp. 111–112.

[25] Minority views of Hon. Michael J. Harrington in opposition to H.R. 15495, 92d Cong., 2d sess. H. Rept. 92–1149 (1972), p. 104.

fense missions.[26] This makes it difficult for Congress to review resources allocated to agencies and to major system acquisition programs.

Review of the need for mission capability and the cost of a new program to provide it is not settled, if at all, until after wide system options have been eliminated and the evolution of a preferred system has been paid for during years of funding through RDT&E accounts with only fragmented congressional visibility. When a new major system does emerge for congressional consideration, all the issues of needs, goals, options, and defense capabilities surface, but the debate then can become too protracted or fall off to focus on the merits and faults of the particular system.

Control over procurement and operating expenditures is very difficult because the system offered is the only real option for meeting a defense need. The cost is predetermined by the size and cost of that system, not by the worth of the capability in relation to other needs or in relation to available resources.

From one congressional viewpoint:

> The military procurement hearings before this Armed Services Committee could be the occasion for an annual debate on the nature of our defense posture which could do a great deal to enlighten the American public . . . Rarely do the questions discussed in the Committee's sessions go to the fundamental aspects of the matter before us.
>
> Choices of weapons systems reflect basic assumptions about the world as it is, and equally basic choices about the world as it should be. But in no sense do these questions receive serious airing in our sessions.[27]

This failure is partly encouraged by the timing and format used to present system acquisition programs and by the kinds of questions this format elicits. It appears that the wrong questions are asked early over RDT&E projects and when the right ones are provoked by debate on a particular weapon, it is often too late for the answers to be relevant.

It is reasonable to ask in a consistent fashion at the beginning of new programs what mission capabilities they are intended to provide, debating the need and goals first and specific technical merits of a system only later and in a mission context.

A better and earlier forum is needed for debating national needs and goals and, within these, the needs and goals for new major system acquisition programs. The lack of that better forum has frustrated members of Congress in their attempts to control the allocation of public expenditures in general and defense expenditures in particular.

Cognizant congressional committees need to ask questions like the following before a new program begins:

- What kind of mission capability is to be provided and what will it enable us to do?
- Why do we need this capability and in what situations will it be used?
- How does this kind of capability relate to defense policy and strategy? Is it consistent with and important to executing policy and strategy?
- Unless the program will create a brand new kind of capability, what level of capability do we have today and in the near future?
- What other current systems and programs are contributing to this mission capability; which agencies and agency components are sharing responsibility; and how much are they spending for it?

Comparable questions can be posed for programs and missions of all Federal agencies. They are questions that can also lead to improved management and budgetary controls within agencies.

An agency would present its decisions on

[26] In the 1950's, the Armed Forces sought appropriations for aircraft and missile procurements on the basis of an authorization that was broad and general in its terms. The authorization for naval vessels was slightly more specific. During 1957, the Senate Committee on Armed Services expressed concern over the purpose of system expenditures, specifically the missions of the Army's Nike-Ajax missile and the Navy's Talos missile.

By June 1959, further concern over the missions to be performed by the Nike-Hercules and Bomarc missiles led to passage of sec. 412(b) of Public Law 86–149 prohibiting appropriation of funds after Dec. 31, 1960, to or for the use of any armed force of the United States for the procurement of aircraft, missiles, or naval vessels (items that had been the cause of concern) unless the appropriation of such funds had been authorized by legislation enacted after such date. Similar restrictions have since been applied to other kinds of systems (such as tracked vehicles and torpedoes) and for research, development, test, and evaluation (RDT&E). Although the initial concerns were over the purpose, or mission, for which these funds were being spent, the legislated funding categories were based instead on the particular kinds of items and activities.

[27] Harrington, note 25, *supra*.

those mission capabilities requiring a new major system to replace or add to existing system inventories and identify those needs that were particularly sensitive to time, mission capability level, and program cost results. For DOD, the presentation would include the intelligence and net threat assessment information used by OSD in deciding to initiate an acquisition program.

This mission-related review of acquisition programs should be updated annually so that neither the agency nor Congress would have to commit itself irrevocably to a static view of National needs, goals, and programs. Flexibility to adjust to changes would be retained and resulting agency decisions would be presented annually for review by Congress.

An early review of needs and goals for new systems should help reestablish confidence between Congress and DOD concerning acquisition programs by allowing each to pursue its responsibilities more efficiently. Uncertainties pervade system acquisition concerning what can be obtained, at what cost, and when. In the beginning, only the need and goals can be affirmed, not the best solution or its cost.

Congress should be able to gain visibility over the defense program and the purpose for which systems are being explored, and DOD should have greater flexibility to cope with program uncertainties within this congressional understanding. Congress might be able to devote less time to detailed scrutiny of particular systems or activities and more time to mission capabilities, policy, and priorities. This should alleviate funding delays that are caused by the burden of extended detailed hearings into specific items and projects.[28]

Having confirmed that a mission need merits an acquisition program, Congress might then appropriate RDT&E funds to begin exploring alternative systems.

[28] The implications for alleviating delays in funding for Federal programs is a related extension of Part A, Chapter 7, "Timely Financing of Procurement," which recommends, in part, "making greater use of authorizing legislation covering program objectives, not annual segments of work." There is a general need, beyond major system programs, for the Congress to have a more meaningful forum for debating program objectives as distinct from the annual budget increments to support them. Authorization and appropriation procedures have both come to focus on the annual increments of work.

CONCLUSIONS AND RECOMMENDATIONS

The recommendations that follow are based on these conclusions·

- The responsibility for identifying and defining defense mission needs that require major system acquisition programs has been delegated to each military service. This contributes to some unplanned duplication of new systems from different services to meet similar needs.

- The first decisions on needs and goals for new acquisition programs significantly affect the kind of system eventually procured. Current statements of needs and goals focus on a preferred system product and not on its purpose. This contributes to rising unit costs and the multimission character of new systems.

- Balancing of program cost, capability, and schedule goals is difficult because they are largely predetermined by the "need" for a particular kind of system.

- OSD and the military services do not have consistent hierarchies of defense mission needs. This makes it difficult to coordinate the allocation of resources, mission responsibilities of agency components, and needs and goals for new system acquisition programs.

- Roles and mission overlap causes competition among the military services that directly affects the statements of needs for new programs and the size, cost, and character of new major weapon systems and permits unplanned overlap in systems and their capabilities.

- Current budgeting and funding procedures do not facilitate congressional debate on policy, priorities for different kinds of agency mission capabilities, or the related needs and goals for new acquisition programs. Rather, these issues usually can be examined only after a single system is proposed for large-scale commitments and after large sums have been expended to propose it. This has contributed to the apparent inability of Congress to deal with agency programs in an effective or timely manner, since Congress is being drawn into considerations of the technical and contractual merits of each specific system rather than reviewing policy, priorities, and expenditures from the standpoint of overall national needs.

Recommendation 1. Start new system acquisition programs with agency head statements of needs and goals that have been reconciled with overall agency capabilities and resources.

(a) State program needs and goals independently of any system product. Use long-term projections of mission capabilities and deficiencies prepared and coordinated by agency component(s) to set program goals that specify:

(1) Total mission costs within which new systems should be bought and used

(2) The level of mission capability to be achieved above that of projected inventories and existing systems

(3) The time period in which the new capability is to be achieved.

(b) Assign responsibility for responding to statements of needs and goals to agency components in such a way that either:

(1) A single agency component is responsible for developing system alternatives when the mission need is clearly the responsibility of one component; or

(2) Competition between agency components is formally recognized with each offering alternative system solutions when the mission responsibilities overlap.

Recommendation 2. Begin congressional budget proceedings with an annual review by the appropriate committees of agency missions, capabilities, deficiencies, and the needs and goals for new acquisition programs as a basis for reviewing agency budgets.

CHAPTER 4

Exploring Alternative Systems

This chapter discusses the creation and exploration of alternative systems to meet operational needs. How well this is done will determine the confidence an agency can have in the system it chooses to take into final development and production.

The evolution of a system is described in this chapter in terms of the key decisions that must be made to define a system in progressively greater detail, from the initial formulation of system concepts to final engineering and production designs.

The chapter distinguishes between two kinds of technical activities. The first is undertaken for the purpose of extending knowledge and not for meeting any specific need. These activities are "technology base" undertakings. The second is undertaken for the purpose of finding solutions to meet specific operational needs. These are the activities that create and explore alternative systems.

An orderly and thorough effort to find the best solution to a problem is an integral part of any logical problemsolving process, but some basic questions must be answered:

Relationship of the Technology Base to Candidate Systems

- How rich is the base in new components and organized knowledge and what organizations sustain it?

- What kinds of new and old technologies are forced up from the base for use in creating new systems?

Creation and Exploration of Alternative Systems

- What levels of innovation, new technology, and risk are permitted to enter candidate systems and from what industry and Government sources?

- How are new candidate systems related to agency needs and how is the search for alternatives conducted?

Competition in Exploring Alternative Systems

- What kinds of competition are used to meet given needs?

Financing the Exploration of Alternatives

- How well can Congress see and control the use of funds to create and explore new systems?

BACKGROUND

Even closely related alternatives imply the existence of more than one course of action and the existence of more than one creates, for procurement, the basis for competition. If there are alternatives, there is some form of competition.

Recent system acquisition programs have been intensely competitive, but the alternatives offered and the way they have been evaluated limited the kind of competition and the ground rules for selection of a system.

In talking of competition generally, it is customary to speak in terms of price as the pivotal factor in deciding to buy one product and not another. However, the actual occasions of pure price competition are rare; in considering a number of products to meet a given need, the relative quality of the products usually enters into the decision.

In most procurement situations alternatives are available and products can be compared readily and a choice can be made. However, if competitive products do not exist for direct comparison, alternatives may be "offered" in response to an expression of need, but they are only promises until developed and demonstrated.

If a company proceeds to develop a product, it takes the risk that the product can't be made to work and that there will be no need for it by the time it is ready for a practical application. Innovative firms take such risks in commercial markets.

In the case of major systems, a company rarely risks its own resources to reduce an idea to a practical application. A few of the reasons are:

- The investment needed may be too great to be risked by one company.
- The Government may be the only potential customer; the merit of the endeavor is linked to the Government's need for it and the need may change or disappear.
- When a system, at the outset, is only an idea, a company cannot be sure how much risk investment it must make. There may be technical unknowns that are impossible to estimate.

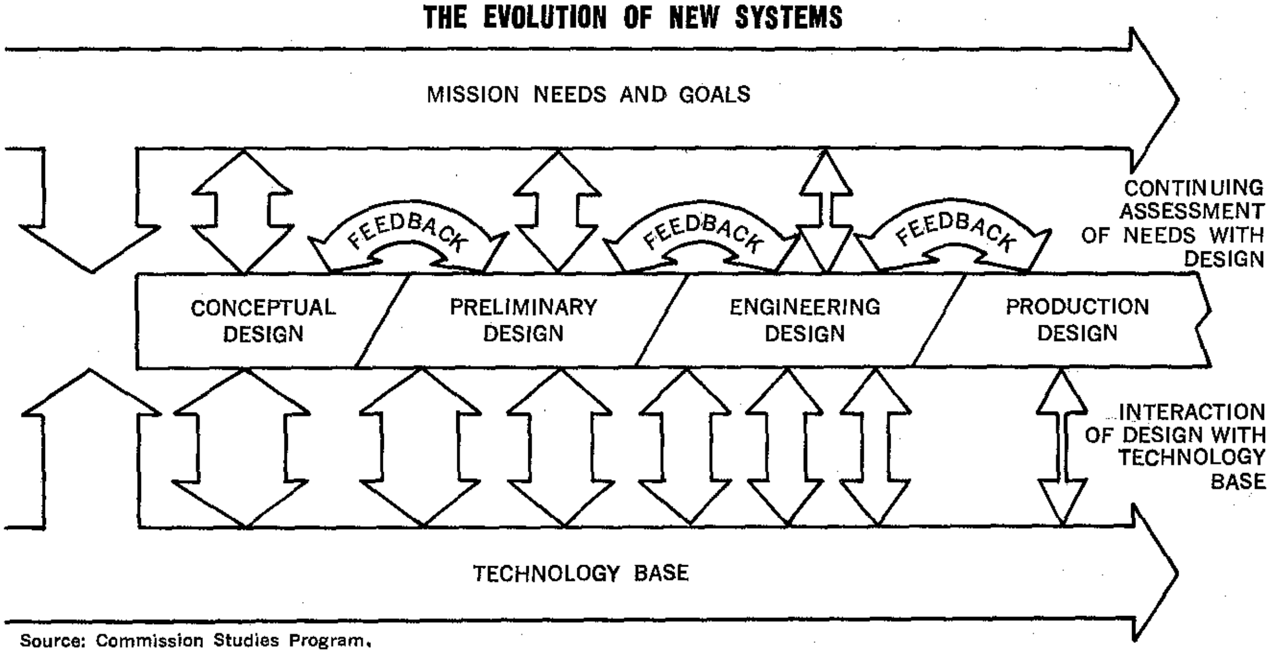
These conditions pose special problems in buyer-seller relationships. Usually, the Government as the buyer must assume a share of the investment risk, paying for exploration of projects it rejects as well as for the products it eventually buys. Therefore, the Government must somehow limit the kinds and numbers of explorations it sponsors.

The number of systems to explore through development depends, in part, on the Government's confidence that mission needs will remain unchanged during development and in part on the technical payoff predicted for each candidate system.

Evolution of New Systems

There is no step-by-step formula for creating and developing new systems into final form, but for every system decisions have to be made on the basis of a sequence of progressively more detailed design activities. These activities and decisions are measures of how far the system has evolved. As decisions are made, subsequent exploration is conducted within the limits established by those decisions (see fig. 1). For example, if a decision is made to choose one concept, preliminary design effort will be focused on that

THE EVOLUTION OF NEW SYSTEMS



Source: Commission Studies Program.

Figure 1

single concept. At each stage of activity, the program's mission need and goals interact with the technology base, both of which could be changing in unpredictable ways.

Conceptual design activity provides a basis for deciding the "system concept," that is, the operating approach and the technologies to be used. These are very broad decisions to limit further exploration to one operating approach (for example, manned aircraft or land-based missiles) and set of technologies to be relied upon, (for example, the kind of aerodynamics, propulsion, guidance, and structures). The chief designer of an aircraft will be assisted by experts in related technologies such as flight dynamics, avionics, structures, aerodynamics, life support technologies, human safety, and aircraft propulsion. Similarly, a chief missile designer will be assisted by experts who are abreast of recent developments in such fields as midcourse and terminal guidance, solid- and liquid-fuel propulsion, warhead technologies, structures, and flight dynamics.

Preliminary design activity decides how the chosen concept and technological parts will be sized and interrelated. For example, the preliminary design for an aircraft takes the chosen propulsion and aerodynamic technologies and packages them into a form that specifies the size and arrangement of the aircraft. In so doing, the designer must begin to balance the different capabilities of the system. For example, increasing the weight of an aircraft means a reduced range, ceiling, rate of climb, and increased takeoff and landing distances, unless better engines or aerodynamics can be found to compensate.

Preliminary design decisions are supported by tradeoff studies that vary one design feature, such as weight, while holding the others constant to see the overall effect on predicted system performance. The results are critical to the eventual cost, availability, and performance of the system. Tradeoffs also identify technical areas where sufficient data does not exist as well as refine the size, shape, and cost of the system.

Engineering design activity refines the size and arrangement of the preliminary design, deciding in greater detail what the parts of the system should look like and how they will fit together in final form. This makes it possible to determine in a narrow range how the system will perform and what it will cost. How realistic these estimates prove to be depends on the extent and quality of information used to verify the design in paper or hardware form.

Information from the technology base or from tests may prove that original selections of technologies will not produce the expected benefits. If such is the case, the further tradeoffs that must be made could result in changes in the dominant technologies (system concept) or the way in which they were initially put together (preliminary design). Most engineering design tradeoffs refine the system to a point where it is possible to fabricate test models of the system.

Production design activity takes the results of all previous design decisions and translates the engineering design into a detailed specification suitable for producing the system in accordance with available manufacturing processes and facilities. Design and production engineers will have exchanged information to make design decisions long before this point, however. Without this early coordination, the designer might have conceived a system that would be difficult and expensive to fabricate and produce.

The end result of this technical activity is a production specification. During fabrication and test, further engineering is used to reduce the cost of producing the system.

PROBLEM DISCUSSION

Four primary problems in current procedures for exploring alternative systems involve: adequacy of the technology base for candidate systems; actual formulation of alternatives; narrow technological concepts pursued in conducting industry competitions; and effectiveness of congressional review and agency funding of system explorations.

The technology base is inadequately developed to serve new acquisition programs and the search for candidate systems. Not only are innovations constrained but frequently, technology base activities do more than provide basic information supporting new systems.

The base may include subsystems fully developed independently of candidate systems. Also, total system concepts may be proposed independently of determinations of mission needs.

The search for alternatives in connection with a specific operational need frequently is conducted in a way that nourishes the technology base in constrained areas of relatively "old" technologies. The net effect is a closed cycle; innovative technologies are suppressed and relatively stagnant ones are carried too far as subsystem and system candidates in anticipation of a specific program.

The formulation of alternative systems suffers from premature commitment to system concepts and preliminary designs because of a predetermined design linked to a statement of "need" and the motivational pressures of agency components responsible for creating new systems. These premature commitments are made to a system that reflects design contributions from many public and private organizations. This "design by committee" cuts off real alternatives and results in a complex and not easily managed "required" system.

Competition in system acquisition is ineffective because of the way new products are explored and created to meet agency needs. Because design decisions on the best approach are made by the Government, contractors compete to develop and produce a "required" system, not to offer their best, low cost solution.

Congress and agencies are placed at cross-purposes by procedures for financing system exploration. Budgets that support technology base activities and early exploration of candidate systems are a melange of thousands of projects that cost billions of dollars. Congress has attempted to review and approve these expenditures on a project basis, thereby reducing the flexibility of agencies to explore new systems without gaining Congress a view of the purpose for these expenditures in terms of national needs.

Adequacy of the Technology Base for Candidate Systems[1]

The technology base is the total reservoir of organized knowledge from directly and indirectly sponsored basic research into physical and social phenomena and the feasibility of new processes, techniques, and components for using them. Its end result is new organized knowledge. The base also retains fallout contributions left over from the exploration and development of specific systems. The creation and exploration of candidate systems, in turn, is shaped by the information available from the technology base.

The technology base is supported by both Government and private activities. Private groups (such as industrial companies) and nonprofit organizations (such as Federal contract research centers and universities) contribute to the technology base and recommend technology base projects.

Within DOD, the defense laboratories are charged with maintaining the technology base by sponsoring technical activities in support of potential systems.[2] Laboratory research objectives are planned to generate better technological tools five to 20 years in the future.

The Joint Chiefs of Staff (JCS) provide laboratory research objectives in an annual document called the Joint Chiefs Research and Development Objective Document (JRDOD). In a complementary approach, the Director, Defense Research and Engineering, has instituted coordinating documents called Technology Coordinating Papers (TCPs). TCPs collect technical effort related to given areas of technology in order to consolidate and control such activity.

It is very difficult to know how much should be spent for technology base activities because payoffs are unpredictable and realized only at some future date. Expenditures for technology base projects are just as important as work to meet specific operational needs, although purposes are different and require different justification. Operational needs can be met most effectively at the lowest possible cost by innova-

[1] Concerns for the adequacy of basic technological resources are examined in Part B.

[2] In 1970, the military services supported 78 R&D laboratories and weapon centers, of which 36 were Army, 26 Navy, and 16 Air Force. The total cost of these activities was $2.5 billion. Of this total, R&D expenditures were $1.7 billion, of which about $1 billion was spent for in-house R&D activities, purchase of supplies and equipment, and technical administrative costs. Employment, both military and civilian, was 68,000. The annual operating cost was over $300 million. Cost of real property and equipment was $2.4 billion, and 50 million square feet of space were used. (Office for Laboratory Management, *Department of Defense In-House RDT&E Activities*, Oct. 30, 1970, p. xvii.)

tive products built on new technology being created for its own sake, as well as that which remains as fallout from other system efforts.

The problem in defense has been to control the relationship between technology base activities and system acquisition programs. Technology base projects have gone on to develop more than just the raw material to meet as yet unexpressed needs. They have developed subsystems and system concepts independently of specific needs. Once developed, subsystems seek a home in new system candidates and system candidates seek a need they can satisfy. Further, these subsystems that have been advanced prematurely by technology base activity increasingly have been old technologies extended to improve the performance of old kinds of products.

CUTTING OFF NEW TECHNOLOGY

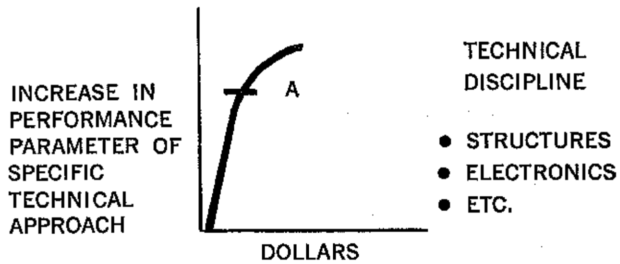
The span of technological work in the defense-related base was constricted starting in the early 1960's and that situation remains today. Technological span was reduced because agency components tended to favor familiar technologies closely related to existing kinds of systems or sponsored them under pressure from agency users and planners. Usually, innovative projects that explore fields of technology not being used in contemporary systems are on the short end of the funding. Technology base projects are screened, in a sense, according to whether they might offer ways to make future airplanes fly faster, farther, and carry more payload; or make tanks and aircraft carriers less vulnerable, go faster, and have more firepower.

Within the military services, technical groups that perform technology base work related to a system coordinate with military technology planners and military operating units in deriving ideas from the base. It is in this early exploratory phase that system alternatives based on widely different concepts and technologies could be developed.

Sponsoring candidate systems that are based on relatively "old" technologies can lead to disproportionately high expenditures for marginally improved new systems, as shown in figure 2.

Initially, for a relatively small investment,

DIMINISHING RETURNS ON USING EXISTING TECHNOLOGY



Source: Commission Studies Program.

Figure 2

significantly higher performance can be obtained from a new technological application, like detection range from radars. At point A, a "knee of the curve" is reached and disproportionately high investments are required for further increases in performance. Asking for a new system to perform 10 percent better may seem a modest request. However, if the request also stipulates that an old and well-matured technical approach be used to achieve it, the system may cost 50 percent more.

All of this runs contrary to the widespread notion that defense systems have suffered because they have embodied too much "new technology" and, as a result, have become too complex, sophisticated, and expensive. The explanation is that what is "new" about "new technology" is the higher levels of performance demanded from old technical approaches.

Subjective ratings indicate that systems, while becoming *more* complicated and expensive, have become *less* technologically advanced. Based on an increasing scale of technological advance from 0 to 20, a sampling of systems of the 1950's averaged 12.2. Systems of the 1960's averaged 8.9, a decrease in technological advance in newer defense systems.[3]

Applying new technology to meet more stringent needs can, in fact, result in simpler, less costly systems. As a common example, the new transistor has markedly reduced the cost and size of electronic systems and improved their reliability, maintainability, and other cost of ownership factors.[4]

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[3] Perry, Smith, Harman, and Henrichsen, *System Acquisition Strategies*, R-733-PR/ARPA, June 1971, p. 14.

[4] A defense industry executive has stated: "I cannot emphasize enough that technology can be used to yield higher capability and

SUBSYSTEMS WITHOUT SYSTEMS AND SYSTEMS WITHOUT NEEDS

DOD proposes to spend about $2.2 billion in fiscal 1973 to support the technology base.[5] This amount includes much more than financing for projects to create new knowledge. It also finances the creation and validation of new subsystems and system concepts.

The creation of new system candidates also is financed by overhead reimbursements for industry technical efforts. In 1971, the defense industry charged $1.128 billion to independent research and development and bid and proposal costs of which $627 million was reimbursed by DOD through overhead.[6] This included not only technology base work but also system-related activities. A significant portion of this indirectly supported industrial effort is directed at preparing for upcoming system competitions.

System-related technology base work done by Government in-house laboratories and weapon centers is paid for through their annual budgets. The allocation process is not precise enough to identify the costs of specific subsystem and candidate system projects.

Nonprofit companies also create new system concepts. These companies act as technical agents for DOD in support of certain mission areas. For example, the Aerospace Corporation supports the Space and Missile System Organization (SAMSO) of the Air Force and creates new military missile and space systems. The Mitre Corporation supports the Air Force's Electronic Systems Division in creating new military command and control systems. System ideas are "paid for" as part of the annual contract funds awarded to such nonprofit corporations, but specific amounts supporting system ideas are not distinguishable from their total budgets.

Government laboratories sponsor subsystems as part of their technology base activities. Characteristically, these subsystems are put into advanced development independently of any system, and later may be directed for incorporation into a system design. The principal argument for developing subsystems independently of systems is that key subsystems take a long time to develop and therefore must be pursued long before a final development effort is to start. The other side of that argument is that systems also take a long time to evolve. If system-level activities were initiated earlier, efforts could be directed first to those subsystems with the longest development times so that they will fit well with the system.

When all system designers are directed to use the same sponsored subsystems, the systems they independently propose will be similar, as a result of accommodating the subsystems. Alternative systems are narrowed in technical differences and the basis for a technical choice of one alternative over others is limited to relatively unimportant design features.[7]

Even when subsystems are not directed into the system, the winning contractor will have a narrow base from which to solicit proposals if key subsystems are defined before the system is competed. Only subsystem manufacturers that have been sponsored will be in a position to compete effectively.

A follow-on consequence is that if something goes wrong during development of the system, it becomes difficult to sort out responsibility for the cause of the problem. It could be the agency that initially sponsored the subsystem and later directed its use. It could be the system contractor who, in many cases, becomes totally responsible for the system although he had no direct control over the subsystem development.

Examples of directed subsystems are the engines, air-to-air missiles, and fire control systems that were directed to be used when contractors competed for both the Navy F–14 and Air Force F–15 fighters. The subsystems in both cases had been sponsored by the

at the same time to reduce complexity and cost." Thomas V. Jones, *Weapon Systems Acquisition Process*, statement before the Committee on Armed Services, U.S. Senate, May 12, 1972, p. 2, mimeo.

[5] Hon. John S. Foster, Jr., *Weapon Systems Acquisition Process*, statement before the Committee on Armed Services, U.S. Senate, Dec. 3, 1971, p. 84.

[6] Defense Contract Audit Agency (DCAA), *Independent Research and Development and Bid and Proposal Costs Incurred by Major Defense Contractors in the Years 1970 and 1971*, a report, Mar. 1972, p. 1.

[7] "Requirements to use existing components can be viewed as constraints on a design. . . . It is easily demonstrable that as one relaxes constraints . . . the payoff must increase, or at least not decrease . . . it will always seem that superior design can be achieved in an engineering sense with a *smaller* rather than a larger proportion of existing components." T. K. Glennan, Jr., "Issues in the Choice of Development Policies," in Marschak, et al., *Strategy for R&D*, p. 38.

Government separately from the F–14 or F–15 aircraft systems and then directed into the competitions.

If a system design team attempts to reject the directed use of a key subsystem for what it considers to be substantive reasons, it reduces its chance of receiving the award if it is not disqualified as "non responsive" to the terms of the competition.[8]

In summary, technology base work (both public and private) tends to concentrate on producing results that are, first, immediately useful and, second, acceptable. To be useful, the work tends to provide well-developed products (both subsystems and system concepts) before the need for a system has been established and confirmed at the agency level. To be acceptable, these products tend to be based on familiar approaches.

The reason for this was abstracted by former Deputy Defense Secretary Packard:

> . . . On top of [other] specific pressures is the basic inertia against change and innovation characteristic of a large organization. One particular characteristic of a military organization is that it tends to think more in terms of getting what was effective in the last war rather than thinking ahead in an imaginative way about what might be needed for the future.[9]

But not all programs have been constrained by the existence and directed use of key subsystems. The Apollo program had subsystems shaped by the needs of the system, not the other way around. Also, when the technologies of ballistic missiles were used for the Atlas and Polaris, most of the critical subsystems had not been developed. As a result, the subsystems were tailored to the needs of the system and evolved with the total system.[10]

[8] ". . . some of the Department's [DOD] laboratories display a not-invented-here attitude that inhibits objective consideration of IR&D products as alternatives to laboratory-originated technological approaches." Blue Ribbon Defense Panel, *Report to the President and the Secretary of Defense on the Department of Defense*, July 1, 1970, p. 66.

[9] U.S. Congress, House, hearings on DOD Appropriations, FY 73, statement of former Deputy Secretary of Defense David Packard, part 3, p. 211.

[10] In addition to these specific instances, the Defense Science Board saw more widespread benefits for early integration of subsystem development, stating that: "we should make sure that the advanced development [of subsystems] gets done—and done under the control of the system designer. He can use the laboratories if he wishes. If he does, he will probably end up with some control over exploratory development." (Defense Science Board, *Final Report on Systems Acquisition*, July 1969, p. 81.)

Subsystems that exist or are in development for other systems are always an optional choice for a system designer. If competition exists between design teams, they will have good reason to consider existing subsystems carefully because use could reduce costs and make their designs more competitive.

The need for an active and viable technology base is extremely important. The larger the span of technical and scientific activity sponsored by the Government, the more extensive will be the optional technological choices available to the system designer. What must be avoided, however, is locking the system designer into a design by directing use of specified subsystems. The more subsystems are directed, the more the competition between design teams hinges on relatively unimportant technical differences. An equally important consequence is that the national technology base will shrink because the private sector will be constrained to "innovate" systems that perpetuate traditional subsystems. The resulting similarity in new systems represents a stretching of old technology, leading to reduced cost benefits.

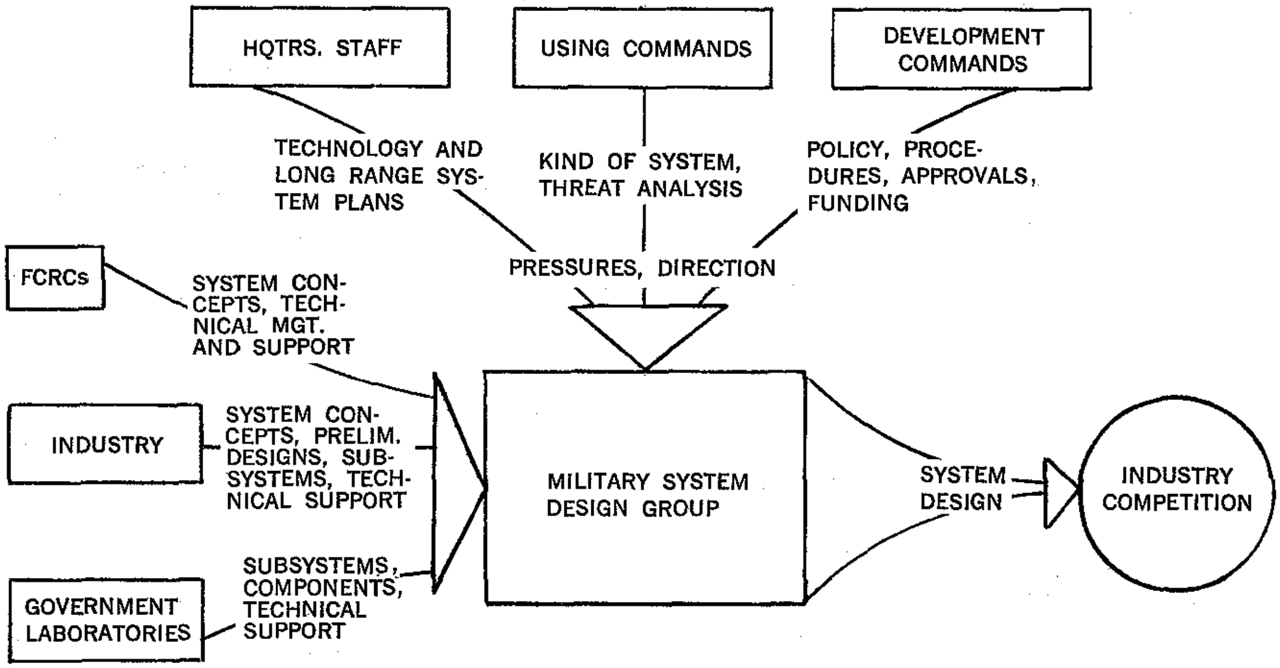
The System Requirements Process

The exploration of alternative systems is called, in military parlance, "the requirements process." The results of system exploration form the basis for requirements documents that follow the first statements of the agency's required operational capabilities (the "need" statement). These requirements form the basis for a design specification and industry competition by reflecting the results of decisions on system concept and preliminary design and the "required" combination of performance parameters that technical exploration says can be achieved. For example, Navy requirement documents are organized to present a system description, performance characteristics, the quantity required, and the date the first production unit is to be delivered to the operating forces.[11]

As shown in figure 3, the basic current pattern of exploring alternatives begins with con-

[11] OPNAV Instruction 3910.6c, *Specific Operational Requirements (SOR); instructions for preparation, coordination and review of*, Office of the Chief of Naval Operations, Mar. 1970.

PRESENT BASIC PATTERN OF EXPLORING ALTERNATIVE SYSTEMS



Source: Commission Studies Program.

Figure 3

tractors and other organizations providing information on system concepts and preliminary designs to agency design groups. These groups assimilate the information and accommodate the directions received from other commands. Choices are made on system concept, preliminary design, and engineering design features. A baseline system emerges whose predicted performance, cost, and schedule attributes become the basis for system "requirements" and formal industry competition.

The next section describes the activities that generate system requirements, in particular the roles played by agency system design groups and industry contractors.

AGENCY SYSTEM DESIGN GROUPS [12]

The Air Force aircraft system design group (fig. 4) is an example of an organization that coordinates system requirements. This group is responsible for managing system exploration activities before approval of a military requirement for a particular system.[13] The other services have similar groups.

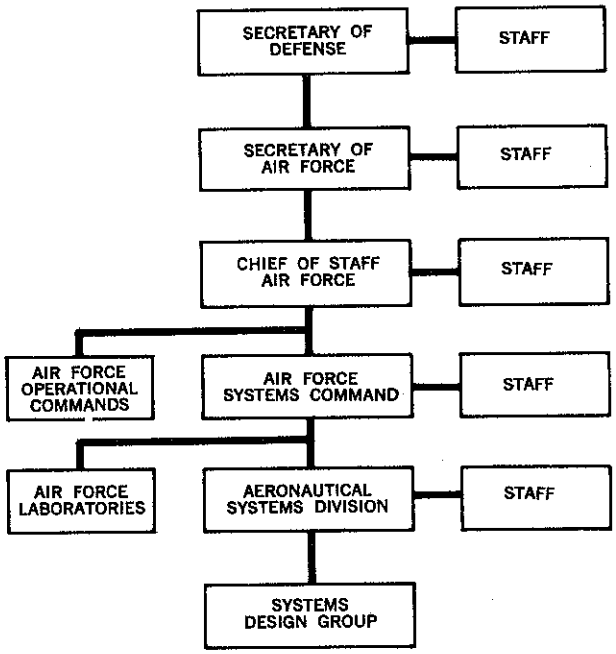
The military design groups both receive and help to write advanced system planning studies. They also receive new system ideas from many other organizations, including industry and Government laboratories. Military system design groups transfuse nonproprietary ideas or innovations as the exploration heads toward a system concept and preliminary design specification suitable for later industry competition. With limited hardware tests to check out critical technical areas and faced with unpredictable technical complexities in the future, the selection of features to go into the preliminary design depends primarily on judgment.

The military design group is not challenged

[12] Under a "weapon center" concept initiated in 1966, the role of some in-house laboratories was to be expanded to a full weapon system level. A weapon center is a self-contained, design engineering, development, and testing organization. On rare occasions, it may act as a single source for weapons for which it has assigned responsibility. Early weapon center relationships with industry exist on a componentry and subsystem level. For example, the Naval Weapons Center at China Lake controls the development of the next Navy/Air Force close-in, air-to-air tactical missile (Agile).

[13] U.S. Air Force Systems Command, Pamphlet 800-3, *A Guide for Program Management*, May 14, 1971, p. 2-3 and *Aviation Week and Space Technology*, June 26, 1972, pp. 32-34. The design group is the responsibility of ASD's Deputy for Development Planning.

LOCATION OF THE SYSTEMS DESIGN GROUP (AIR FORCE)



Source: Commission Studies Program. Similar illustrations could be made for the Army and Navy; the Marines do not have a development command.

Figure 4

competitively in its role as focus for deciding system concept and preliminary design. One observer has commented:

> In the private economy other competing firms can duplicate or take different points of view about the nature of desirable products. But there are not two departments of defense to provide the competitive survival and selection of preferred products . . . Without competitors . . . a monopoly does not ensure that alternatives will be tested and explored with the efficiency of competing firms.
>
> A quiet, uncomplicated life without so much bickering and fighting about wealth values of alternative products is more viable. Centralization under Government contexts implies less exposure and testing of differences of opinion, easier suppression of alternatives, less effective response to costs, and less flexible adjustments of programs despite more exhortations to the contrary.[14]

The Aeronautical Systems Division of the Air Force oversees the initial design evolution of all future Air Force aircraft. On occasion, another military service may implicitly compete with that division's design approach when the assigned roles and missions of the two services overlap. If such a situation develops, higher headquarters of both services have an interest in altering their systems and plans so that both would be acceptable at agency head levels.[15] This implicit intragovernmental competition, when it exists to solve defense needs, encourages:

- The motivation to scratch each other's back, to support a program of another military component if that component, in turn, supports a program of theirs.
- The motivation to distinguish a system from that of a competing service and, hence, the motivation to reward technical complexity when it minimizes apparent interservice competition.
- The motivation to be the first of the competing services to gain large-scale program commitments and, to achieve this end, to: by-pass time-consuming system-level testing; prematurely claim a low technical risk; understate costs and schedules and overstate performance; and eliminate alternatives.

It is impossible to formally document these motivations or to prove that they have been factors in causing increased complexity of new systems, in general, or any one system in particular. The point is that there is little visibility over the environment in which early technical decisions are made and interservice rivalry comes into play.

Other pressures are brought to bear on the "requirements" for a new system. Higher commands are interested so that, service rivalry

[14] A. A. Alchian, "Cost Effectiveness of Cost Effectiveness," in *Defense Management*, S. Enke, ed., pp. 80–81.

[15] "The increase is frequency of unanimity in the recommendations and advice of the Joint Chiefs of Staff is by no means conclusive proof of subjugation of particular service views. Such frequency of unanimity can just as cogently support a conclusion that the basis of such recommendations and advice is mutual accommodation of all service views, known in some forums as "log rolling," and a submergence and avoidance of significant issues or facets of issues on which accommodations of conflicting service views are not possible." Blue Ribbon Defense Panel, note 8, *supra*, p. 8.

aside, several features may have been added to the maturing candidate system through staff actions.

While innovative system ideas may be suggested by many groups, the agency technical group picks and chooses those features that, in its opinion, best match the anticipated needs of the military user and the direction received as a result of bureaucratic factors mentioned above. Industry contractors working through informal channels, however, are the principal sources of information used by agency design groups as a basis for their "requirements."

THE ROLE OF CONTRACTORS

To meet corporate growth objectives, companies often come up with new system ideas as a result of independent efforts. The information that comes out of this effort is useful to military system design groups and companies can market some of their ideas to such design groups.

On occasion, responsible agency design groups are subjected to intense pressures by contractors who are interested in staking out technical positions for the large system development that may follow. A contractor may have "sold" some of his ideas at the higher headquarters:

> Then there is the pressure from industry. Private firms try to sell their particular program not only to people in the services but also to people at the secretarial level on the E ring of the Pentagon and . . . to influencing committee members of the Congress.[16]

Although often selling hard, the information supplied by contractors on possibilities for new systems is distorted by several policies and practices that perpetuate old system solutions for new problems.

A company that proposes that its idea be explored further could receive a contract. At the same time, companies are reluctant to use this unsolicited proposal route for truly innovative approaches because these ideas will find their way into competitive solicitations sent to industry if they are adopted by an agency system design group. Moreover, if a contract is awarded sole-source, a company must share the cost of the development effort. If further work is encouraged, it normally is covered through partial reimbursement of charges to overhead expenses.

Independent company efforts are directed toward technology areas where interest has been expressed but the "reasons" for the interest have not. Companies tend to see new candidate systems as improvements to those currently in use and tend to propose them to the military customer for whom they previously have developed and produced a system.

There are other factors that limit the kind of new systems created and proposed by company design groups. Even the existence of subsystems sponsored by Government laboratories modifies a company's approach toward creating new system ideas. Good business sense constrains the company innovator to include such subsystems. This constraint tends to level the approach taken by all companies interested in a given mission area to suit the customer's apparent predilections.

Corporate managers also recognize the probability that competitors are working on systems that are similar, conceptually, in order to satisfy the agency's preferences. An intense marketing effort unfolds as each company attempts to distinguish its offerings from its competitors by creating unique features within a common system approach. To do this, a company has to strike a delicate balance between new features and the customer's basic idea of what he "needs." Companies plan technical efforts to obtain study contracts used by military design groups to refine system design, thereby getting ready for a competition to engineer the total system.

In all the above circumstances, marketing considerations cause optimism in company representations of alternative systems, in what they will do, what they will cost, and when they will be available. Such technologically constrained and optimistic data becomes basic information for the baseline system design reflected in military requirements.

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[16] U.S. Congress, House, Committee on Appropriations, *Department of Defense Appropriations for 1973*, hearings before a subcommittee, 92d Cong., 2d sess., Feb. 22, 1972, part 8, p. 211.

OUTGROWTH OF THE REQUIREMENTS PROCESS

The most prominent result of the requirements process just described is that there are not substantive alternatives when program development funds are requested and formal industry competition is introduced.

The basic pattern for exploring alternative systems is to direct technical activity toward verifying that the "required" system, as compiled from multiple information sources, will perform and be available as predicted. After the initial span of alternative systems has been reduced through studies, available resources have been used to make sure that the original decision was a good one. Because performance and schedules have been treated as imperatives, later technical activity has been directed more at making sure the requirements were met than at making changes in response to new information or later assessments of need.

Technical decisions based on studies and limited tests from all available sources provide for economy in defining a system. Studies are cheaper than hardware testing and are available earlier in the process. Use of this early information has enabled an agency to write a system requirement specification in enough detail to hold an industry competition.

Later system difficulties sometimes prove that this approach is a false economy. When alternative systems have been eliminated by the time of the first agency head decision in the acquisition process, the Defense System Acquisition Review Council (DSARC I), there is no further competitive challenge to the system. OSD usually must continue with the selected system, even if serious technical difficulties arise later.[17]

The early and detailed lock-in of systems can be seen from an analysis of development concept papers (DCP) illustrated in table 1. These DCPs were developed for first agency head decisions on four new programs. Early constraints included system weight (to five significant figures), climb rates, altitude, maintainability, reliability, special radar modes, ranges, miss distances, accelerations, power/weight ratio, wheel size, road speed, quietness, time to fire, number of engaged targets, speed, payload, loiter time, load factors, the dates set for initial operational capability, and cost.

To summarize, the basic current pattern of exploring alternatives still is to have a single agency organization choose a system concept, preliminary design, and main design features based on information provided by multiple sources. Early exploratory work, in the absence of a formal need statement, forms the basis for a military system requirement at a later time. After approval, system technical work focuses on the refinement of one preliminary design. All but engineering design alternatives will have been eliminated.

In essence, the Government has taken over the responsibility for early definition of new system products through a series of largely unchallenged technical decisions on system concept and preliminary design. Any "challenge" provided by layers of staff reviews is costly and largely ineffective in providing clear-cut alternatives. Some of the most serious outgrowths of these practices are felt in the for-

TABLE 1. SYSTEM ALTERNATIVES REMAINING AT FIRST AGENCY HEAD REVIEW

Case A

(1) Accept the system as proposed by the service.
(2) Cancel and undertake development of a new system for joint service needs.
(3) Cancel and rewrite requirements.

Case B

(1) Proceed with proposed system using prototypes.
(2) Modify existing inventories instead.
(3) Cancel and do more studies.

Case C

(1) Approve two systems as proposed by services X and Y.
(2) Approve system X and cancel Y.
(3) Approve system Y and cancel X.
(4) Cancel both and develop joint requirements.

Case D

(1) Proceed with system without prototypes.
(2) Proceed with system with prototypes.
(3) Cancel and upgrade existing inventories.

Source: Development Concept Papers, abstracted for purposes of declassification.

[17] "Programs like MBT–70, C–5A, and the F–111 get defended before Congress and the American public—whatever their problems in performance, cost, and schedule slippages—simply because the Services haven't had alternatives they can bet on instead. It's like betting on one horse races—the winners, too often, turn out to be real losers. The ante's especially expensive when the nag drops dead halfway down the track—like the Cheyenne and the F–111B." "No More One-Horse Races," editorial, *Armed Forces Journal*, Nov. 22, 1969, p. 6.

mal industry competitions for new system acquisitions.

Competition in Exploring Alternative Systems

Chapter 3 pointed out that mission need statements, program goals to be achieved, and operating constraints on the system solutions should not be based on a specific system. When done this way, the design group has maximum latitude to innovate a system solution to the need.

Different design groups have different approaches to the same problem. It is unlikely that one group will exactly parallel another in cumulative experience and expertise. As a result, formal competition will be able to capitalize on any differences in concept, preliminary, engineering, or production design approaches.

COMPETITIVE DESIGNS

The existence of alternative system designs creates the potential for competition from the earliest point in development. Table 2 describes the types of competition that may be involved, depending on how far the system has progressed in development. Customarily, competition has been introduced at the engineering design stage, ignoring the potential for competition in system conceptual designs.

Each solution based on a different technical approach would be considered an alternative system concept. These concepts could be carried in competition with each other until proved unsound or ruled out by other considerations. The surviving systems could be carried into further definition if the mission need remained. This first type of competition could be termed *conceptual competition.*

There may be occasions when conceptual differences are not possible. This could happen when the stated mission operating constraints clearly admit only one conceptual solution, say, for example, land-based missiles. However, independent missile design groups most likely would arrange and package the common technologies into different preliminary designs that could create marked differences in the cost, performance, and schedule expected of each system. These system designs would compete to meet the mission need. This second type of competition could be called a *preliminary design competition.*

A third kind of competition is *engineering design competition* with each system candidate defined within the limits of concept and preliminary design. In this competition, a balanced set of system performance characteristics already would be predicated on a preliminary design. Remaining design latitude would be limited to such things as system weight, size, and arrangement. Each competitor's product would look, cost, and perform essentially the same.

Once a system has been developed, tested, and produced in some limited quantity, proven production drawings and processes could be the basis for competition of subsequent production quantities. This would be the fourth type, a *production design competition* with price dominating selection of a supplier. "Alternatives" here would be differences in sell-

TABLE 2. TYPES OF SYSTEM COMPETITION BASED ON HOW FAR THE PRODUCT HAS BEEN DEFINED

	*Basis for selection**
1. *System conceptual design* Establishes function; operational approach and technologies open	Innovative concept and design
2. *Preliminary design* Kind of system prescribed; main features open	Main design features
3. *Engineering design* Main design features prescribed	Price and qualitative features
4. *Production design* Production drawings, design fixed	Price

*Many other considerations may influence a selection in a specific case: management enthusiasm, contractor capability, geographic location, service preferences, delivery promised, are some. Cost of ownership, a rarely used key factor, is discussed in Chapter 5.
Source: Commission Studies Program.

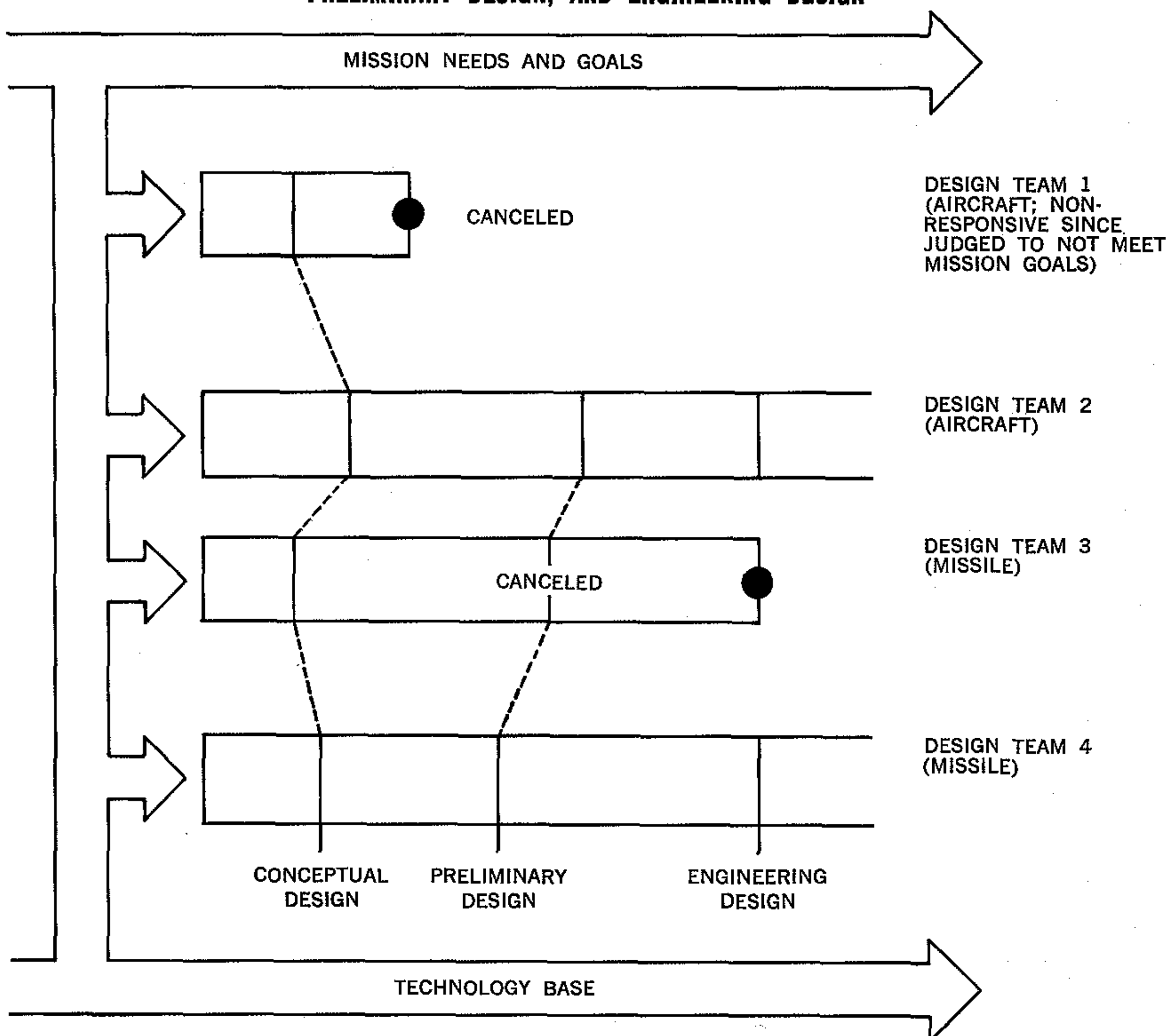
ing price and ownership costs, if the latter is calculated, because all competitors would be proposing to identical work statements.

The first three types of competition are shown in figure 5. For example, design team 1 may have a system concept that is not expected to meet the mission goals and therefore is dropped from further exploration at an early point. Design team 2 may have an acceptable system concept, but it differs from that of teams 3 and 4, which have chosen the same concept. Team 3 may be dropped because of preliminary design difficulties before the engineering design competition, leaving teams 2 and 4 as surviving competitors, each designing very different systems to meet the same mission need.

Design teams would carry out the same fundamental activities, but have different *conceptual* or *preliminary design* approaches, thereby providing different system performance features, effectiveness, and cost of acquisition and ownership.

Most recent programs have been basically "engineering design" competitions (shown as number 3 in table 2 and commonly referred to

DESIGN TEAM COMPETITION IN SYSTEM CONCEPT, PRELIMINARY DESIGN, AND ENGINEERING DESIGN



Source: Commission Studies Program.

Figure 5

as "design competitions"). The previous section on creating and exploring alternatives explains the reasons for this—information and decisions on alternative concepts and preliminary designs have been centralized within the agency. In addition to foreshortening the examination of wide alternatives, this procedure limits those who are eligible to compete and has a significant and widely felt impact on the structure of industry.

COMPETING USSR DESIGN BUREAUS

The Soviet Union makes explicit use of intragovernmental competition.[18] The United States has two fixed-wing aircraft "design bureaus" (the Naval Air Systems Command and the Air Force Aeronautical Systems Division) and one helicopter "design bureau" (the Army Aviation Command). The USSR aviation ministry has two helicopter, eight fixed-wing aircraft, and six engine design bureaus. It also has at least six research institutes.

There is, in its production ministry, a very important scientific council with membership that includes representatives from the production ministry, from user organizations, scientists from the research institutes, and representatives from the design bureaus. It is a standing committee with a high level of experience and understanding.

A requirement comes to this committee for review. If the committee finds merit in the proposal, it may pass it on to several different designers for further development. The committee may recommend changes in the proposal before proceeding further, or they may reject it.

Five or six different designers may work on a proposal, each competing with the other. The several preliminary designs are returned to the council for a review that can be very extensive. Often, one or more competitors may be sitting on the council when a designer goes before it to have his plan approved. At this stage, two or three preliminary designs may be selected for further work. All may be rejected if it looks as if the job can't be done reasonably. The design bureaus selected to continue the development will engineer, fabricate, and conduct development tests. An independent institute tests all aircraft competing for the same mission.

This scientific council acts as a technical source selection authority, monitors the progress of competing design bureaus, and can cancel a competing design if progress is not satisfactory.

Although its economic system is the antithesis of a capitalistic one, the Soviet Union has adopted a pragmatic system of experimenting with wide competing options before making decisions.[19]

ELIGIBLE COMPETITORS FENCED OUT

For many years, only the established, larger firms in the industry have been allowed to compete for systems because, at the late point at which most competitions were held, the winner had to have capacity to proceed with full-scale development and, relatively soon after that, production.[20]

Medium and small firms have been fenced out of a direct and continuing relationship with the Government as sources of technological innovation on a system level by reason of limited facilities and capital but not because they lacked innovative solutions.[21] When competition is held for final development and production, extensive plant and equipment will be

[18] The material in this segment is drawn from the testimony of A. J. Alexander of RAND before the Senate Armed Services Committee (to be found in the Report of *The Weapon Systems Acquisition Process*, hearings, 92d Cong., 2d sess., Dec. 8–9, 1971, pp. 193, 197). It also includes information gained from an interview with Mr. Alexander and from his publication, *R&D in Soviet Aviation*, R–589–PR, Nov. 1970.

[19] An industry executive has commented: "I am left with the impression that the Soviet Union has devised a very strongly competitive climate for the development of their aeronautical products. It would appear that nearly always there are two *entirely different* products under production procurement for each acknowledged mission. The air show leads me to believe that these parallel production competitive procurements are chosen from a still larger number of prototype systems." [Italics added.] George S. Schairer, "The Role of Competition in Aeronautics," The Wilbur and Orville Wright Memorial Lecture, Dec. 5, 1968. London, Royal Aeronautical Society.

[20] The long-term effects of the high cost barriers to entry to major acquisition programs is evident in the apparent "lock in" of major defense contractors. Data from the ASD (Comptroller) on prime contract awards shows that 18 of the 25 top contractors in 1958 still were in the top bracket 11 years later, in 1969. (U.S. Department of Defense, *100 Companies and Their Subsidiary Corporations Listed According to Net Value of Prime Contract Awards*.)

[21] ". . . the relative ease with which new (and generally small) firms can enter the industry may be more important than the statical properties of the size distribution of firms. In many industries new entrants have been a prime source of invention; they were often founded by individuals for the specific purpose of carrying out inventions and innovations . . ." Nelson, Peck, and Kalacheck, *Technology, Economic Growth and Public Policy*, a RAND Corp. and Brookings Institution study, 1967, p. 71.

required as a qualifying condition for competitors. A small firm is not considered qualified for such competition.

The restrictions that keep smaller firms from competing with system alternatives, and the dominance of the large firms that do, may be contrasted with the observations of a study on technology, economic growth, and public policy.[22]

This study pointed out that large firms could dilute competition and affect innovation by limiting the chances for new ideas to get a trial. It pointed out that making it easier for smaller firms to submit their ideas for a "fair" trial would serve as a check against the risk aversion tendencies of established firms. Competitive ease of entry for all qualified innovative sources is particularly important when technology is advancing rapidly.[23]

If entry costs were reduced and smaller firms were used as sources of system innovation, the span of choice would be widened. As previously noted, early decisions on technical approach that initially describe competing alternatives are vital to an effective system acquisition effort. These early alternatives are not costly to explore initially. Early technical activities are highly sensitive to technological innovation and do not require ownership of large plant and equipment in order to explore and validate the key components and assemblies that are the basis for a new candidate system.

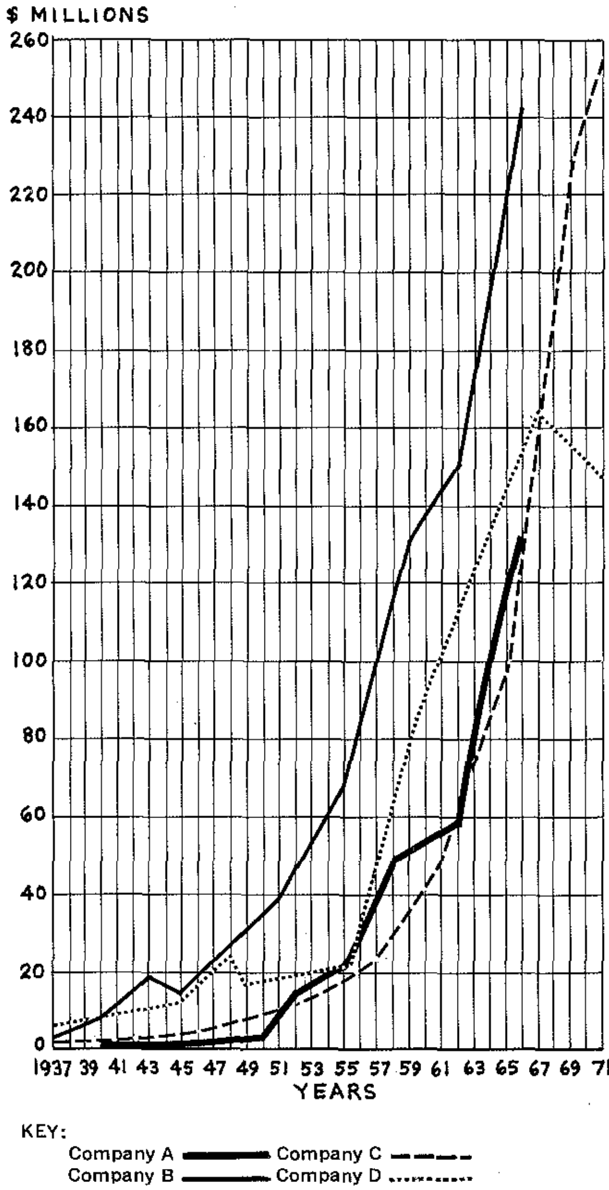
Smaller companies that have technical personnel of broad system experience should be permitted to enter and challenge the larger ones and thereafter maintain a continuing relationship with the Government based on the merit of their efforts. If their products prove superior, the necessary plant and equipment could be bought or leased from those sources who have it today or newly created if existing plants are obsolescent. If *special* facilities are required, they could be provided by the Government, as is being done today with the larger firms.

[22] Joint RAND/Brookings Study, note 21, *supra*, p. 69.

[23] These conclusions find support in the following: "One of the great tragedies in the development of this military/industrial/university situation in this country, is the fact that it is becoming more and more clear that the medium-sized company, let alone the small company, is having less and less of a chance to bid. Based on experiences in World War II, when smaller companies were cut in, they often did a better job than the big companies." Hon. Stuart Symington, Member, Senate Armed Services Committee, in: U.S. Congress, Senate, Committee on Armed Services, *Weapon Systems Acquisition Process*, hearings, 92d Cong., 1st sess., 1971, p. 52.

Most major aerospace contractors were once small firms. Figure 6 shows the rapid growth of four major defense contractors in terms of plant, property, and equipment, over the past three decades.

GROWTH PATTERNS OF SELECTED MAJOR PRIME DEFENSE CONTRACTORS IN TERMS OF PLANTS, PROPERTY, AND EQUIPMENT



Source: Data Furnished by Companies.

Figure 6

Although these relatively small firms dealt with what was, at the time, advanced technology, recent experience has demonstrated that technology for current advanced weapon systems also can be handled by small groups. The SR–71 Mach 3 titanium interceptor was created and designed by 135 engineers at the "Skunk Works," a small "company-within-a-company" preserved for over 30 years within the giant Lockheed Corporation.[24]

A mechanism for permitting new system-level entries through competitive challenge has not existed since World War II. System-level innovation has been bound up with system-level production capacity. Although there is currently an industrial overcapacity for production, there would be benefits to DOD in terms of lower cost systems if the competitive base for system innovation were broadened by reducing the entry cost for system competitions.

CREATING MEANINGFUL COMPETITION IN EXPLORING ALTERNATIVE SYSTEMS

Competition is valuable in obtaining superior systems and also is a hedge against an early failure of one or more of the technical approaches.

The use of competition to produce performance and cost benefits for the eventual system user has been described as a way for a customer to receive more for his money. It also has been pointed out that competition will cause many things to happen that would not happen in its absence such as driving prices down and product values up. If competition costs more initially, the additional costs are often more than recovered in lower procurement prices, ownership costs, and higher product value.[25]

Reinstating meaningful competition hinges first on the information being bought to evaluate competitors but primarily on the design latitude allowed them. DOD has made some progress on both fronts.

A military design group may elect to open up industrial system competition before the final military requirement has been approved. If this strategy is elected, the subsequent design management activity is transferred to a prototype office.

There are many different kinds of prototypes, but one type, the operational prototype, is of particular interest. It has been described as:

> . . . low-risk test articles in operationally realistic configurations representing *possible solutions to known military needs.* Through simulated operational testing, we hope to gain an early assessment of the operational utility of *alternative approaches,* while providing an early benchmark for accurate cost estimation. . . . Some of these prototypes will, we hope, lead eventually into full development and operational inventory. . . . Greater emphasis in the foregoing categories of effort will also provide important stimuli and sustenance to our nation's design and basic research teams, all of which constitute the core of our science and technology base.[26] [Italics added.]

The operational prototype will not be a fully developed system. It will be, instead, several important subsystems to be tested in combination. These will not be paper tests such as computer studies which simulate the subsystems. The subsystems will actually exist and so the tests will be hardware tests.

But engineering design competitions that typified the competition used in the 1960's can still be used with prototypes. Even if the agency had prototyped several C–5As, the competition would have been constrained because:

> . . . there were relatively minor differences between competitors . . . The [competitors'] models appeared at first glance virtually identical, . . . there was not much to choose between the technical aspects of the competing proposals . . . and given the natural limitations on freedom of aeronautical design within these parameters, it was perhaps not surprising that three competent airframe

[24] See Clarence L. Johnson, *Weapon Systems Acquisition Process.* Testimony before the Committee on Armed Services, U.S. Senate, May 12, 1972.

[25] Schairer, note 19, *supra.*

[26] Dr. John Foster, Director, Defense Research and Engineering, in: U.S. Congress, House, Committee on Appropriations, hearings on *Department of Defense Appropriations for 1973,* 92d Cong., 2d sess., 1972, part 4, p. 738.

manufacturers should have produced relatively similar technical solutions . . .[27]

The key to reinstating more meaningful competition is not only substituting prototypes for paper in the exploration of alternatives, but also opening the span of product choice for the competitors. Recent prototype programs demonstrate some variance in product decisions made before competition was sought.

The Air Force has sponsored competitive prototypes of a lightweight fighter and will shortly award contracts for a short takeoff and landing transport aircraft. The Navy, too, plans a prototype carrier-based, vertical takeoff and landing aircraft.

For the lightweight fighter prototypes, the Air Force described the design and performance objectives and specified the amount of development money. All contractors proposed to meet the performance objectives at less cost than specified. The dominant airframe and propulsion technologies had been picked before the competition was held. This placed the industry preliminary designers under some constraints but the constraints would have been more severe if the competition had been based on a detailed specification. Because a cost was specified, it implied that the Air Force had done some design work.[28]

The lightweight fighter prototypes will look similar and probably will cost and perform within a limited range. The span of technology to be explored, therefore, does not achieve fully the purpose of either the technology base activities or the exploration of candidates.[29]

The Navy opened up the product latitude for contractor responses in their procurement for a vertical takeoff and landing prototype aircraft system in anticipation of the need for such a system as an adjunct to a small aircraft carrier. The procurement announcement carried elements of a mission problem statement and left technologies free within a manned-aircraft operating approach:

> It appears that at least two general types of aircraft may be useful from this ship: (a) a long endurance, sensor-carrier which may also *deliver weapons against low-resistance targets*, such as submarines and fast patrol boats; (b) a shorter endurance higher performance fighter-attack type for *air opposition and offensive missions against larger ships* . . .
>
> In developing these ideas we intend to explore technological opportunities by hardware prototypes. Subsequently, we will address the establishment of a firm requirement and initiation of engineering development. Minimum cost and minimum time approaches are essential, and we expect the hardware prototypes to be oriented *toward technology rather than full compliance with the many requirements essential to a full engineering development* . . .
>
> *The Navy plans to evaluate imaginative ideas for this concept on a continuing basis.*[30] [Italics added.]

Navy personnel had great difficulty in getting this approach underway, principally because it diminished the role of centralized design activities within the Navy.[31] Staff at the agency head level also questioned the approach because the program did not describe the key subsystems, airframe, and engine in the usual detail. A congressional committee, unfamiliar with this approach to procurement, advised the Navy that the program would be deferred until a more definitive plan could be expressed.[32]

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[27] *The C-5A, A Case Study in Weapon System Development*, Part B, Contract Definition, Jan. 1967, pp. 54 and 55. Prepared by Abt Associates Inc., and Management Analysis Center, Inc., for use by the Industrial College of the Armed Forces. Quoted with permission of the Commandant.

[28] How the Air Force arrived at schedule, cost, and performance objectives in the specifications was told by the program manager: "All through the evaluation period [of contractor proposals], the Air Force checked data with its own design, which it was perfecting along with the competitors' versions. It was designed from the statement of work in the original request for proposal. It's a capability many people don't know we have." "Air Force Had 'Tough Time' Picking Lightweight Fighter Winners," *Aerospace Daily*, Apr. 19, 1972, pp. 285–286. (Interview with Col. L. W. Cameron, Director of the Prototype Programs Office, WPAFB, Ohio.)

[29] "Competitive prototypes have maximum value in comparing widely divergent solutions to the same problem. This is meant to imply that the competition should be between concepts and should not be aimed at saving dollars by having two or more hungry industry members contesting for the prize." Willis M. Hawkins, *Prototypes: Experience and Promise*, Speech, 17th Annual Conference of the Armed Forces Management Association, Aug. 20–21, 1970.

[30] *Commerce Business Daily*, Nov. 18, 1971. Information received from Naval Air Systems Command Headquarters.

[31] B. Schemmer, "Navy's Choice of North American V/STOL Fighter Stirs Intra-Service, Technical, Industry Debate," *Armed Forces Journal*, July 1972, pp. 36–39.

[32] Hon. John C. Stennis, Chairman, Senate Armed Services Committee, *Press Release*, Apr. 26, 1972.

The Navy received several innovative proposals from contractors. They eventually were able to convince those who had challenged the procurement's lack of specificity that it was of an exploratory nature. In the Navy's judgment, one contractor proposed a unique propulsion scheme that, if successful, would represent a major advance in vertical lift technology and the engine arrangement that goes with it.[33]

To reduce constraints on bidders, it would seem prudent not to preselect technologies. The improvement needed in mission capability could be described in broad terms. Exploratory development efforts do not need preconceived answers.

A widening of the technical differences between new systems to meet a need has another important benefit. It hedges against changes in DOD's needs. Accommodation of unpredictable changes in the need, for example, can sometimes be handled by changes to a system under development. When they cannot, a mission need may not be met.

Currently, the authority to proceed with an operational prototype program amounts to approval for an operational inventory system. Go-ahead on the program should depend on its supporting or satisfying an anticipated military need. The competition to select the prototype winners locks those contractors into any succeeding weapon development phases.

If there is to be production, one of the competitors will build the required quantity. The design drawings for the best system, as proved in comparative testing, would not be a realistic basis for a new industry competition. The contractor that develops the winning prototype would be too far ahead.

It is important to give the agency head real alternatives when he makes a decision for procuring a system for operational use. This is why competition should be based on the need for added mission capability to be acquired within certain cost and schedule goals. Such a statement of mission need should not preempt competitors from selecting combinations of technology to form a system. Important technical differences between prototypes would be the basis for a real choice when one must be made.[34]

A range of choices provides more options in the event that a significant change in an anticipated need makes any one candidate system inadequate. Requirements documents will be prepared at a later date and be more meaningful because the required performance, cost, and schedule will be based on both the competitive process and hardware test data.

DOD's current emphasis on competitive hardware testing before committing to a single system makes subsequent procurement efficiencies possible. It also should provide the opportunity for exploring a broader span of competitive system alternatives.

CONTRACTING FOR EARLY COMPETITIVE DEVELOPMENT

Using competition at an early stage raises the question of how to contract. The technical features of alternatives are uncertain at the outset; it would be prudent for the Government and the competing companies to make short-run agreements, with fixed dollars, to solve certain elemental problems present in each system. If initial efforts are successful, the contracts could be extended to cover subsequent sets of elemental problems as long as the approaches remain promising, a company's progress is acceptable, and the mission need remains. The challenge to each contractor is to identify the critical uncertain elements associated with its system and propose the technical activities needed to produce validated test results. The risk taken by the contractor is that he must do the work for the fixed amount of money provided.

The concept here is one of fixed-level fund-

[33] However, the Navy then assigned only this contractor to work on the problem, a "sole-source" procurement approach. From U.S. Congress, House, Committee on Appropriations, Department of Defense Appropriation Bill, 1973, H. Rept. 92, 92d Cong., 2d sess., Sept. 11, 1972, p. 217.

[34] There is support in history for the importance of hardware test of widely different system approaches: "The first question relates to the freedom with which the contracting agency and the contractor can work towards devising new systems. Will they be able to operate with the freedom displayed in the B–18/B–17 competition in which products of very widely differing size and characteristics were prototyped for a very flexibly stated need? This same great flexibility in competition existed later in the competition among B–45, B–46, B–47, B–48, and B–49. The government procurement office was given very great freedom to encourage widely different approaches and was not restricted to a single critically defined system. We must face the question of whether there can be adequate decisions on size and basic characteristics of the product and scope of the system at an early date, or whether there can be great freedom in the early stages." Schairer, note 19, *supra*.

ing of contracts for short timespans related to sequential system exploration. Consideration of uncertainties means that the parties should not be committed to more than one year's effort at a time.[35]

This contrasts to the practice of contracting for system-level development over multi-year periods. The focus has been on contracting for the system and all its elemental problems in one package, taking too big a bite of uncertainties. If an elemental problem (or an accumulation of problems) was not solved, cost growth, schedule slippage, or reduced performance could and often did result. Early commitment to development of the full system assumes that the many known and unknown elemental problems will be solved. This assumption involves great risk. Elemental problems often were not identified until after they caused significant variations in the initial system contract commitments that frequently involved significant financial consequences. DOD's policy response has been to use only cost-plus contracts for uncertain development commitments.

The strategy suggested here is sequential decisionmaking that separates system evolution into discrete steps and separates development from production decisions. The latter already is reflected in new DOD policies. Neither the military service nor a contractor normally will be authorized to move into final development until demonstrated results are available.

Instituting sequential decisionmaking in very early technical activities[36] has two important effects:

- The agency head can reorient the exploration of alternative systems in response to changes in mission need and the appearance of unpredicted technical events.
- Competitive motivations to reduce costs and improve system capability are placed on the design teams competing to solve a common need.

Because of mission need and technical uncertainties, the Government manager of the total program technical effort should be permitted to reprogram funds from one system exploratory effort to another as it becomes necessary to do so, unless the total funding of his mission effort is in danger of being exceeded.

If a fixed budget is set in advance for exploring alternative systems to meet a mission purpose, there is less penalty to the manager if he is free to adjust the allocations among several projects. This argues for concentrating on the best choices within a fixed budget to achieve a stated purpose.[37]

Financing Alternatives: Congressional Review

The military authorizing committees of Congress annually review and authorize appropriations for the total research, development, test, and evaluation (RDT&E) budget proposed by DOD to support technology base activity, exploration of alternative candidate systems, and final development of systems already chosen. The RDT&E budget proposed by DOD for fiscal 1973 is shown in table 3.

Projects to support technology base activity as well as early system alternatives can be found in the first three categories—research, exploratory development, and advanced development. The remaining categories, for the most part, finance approved engineering design activities associated with the final (or "full-scale") development phase.

Not counting the operational systems development money which can be allocated by system to the main force missions, the R&D funds in fiscal 1973 total $6.8 billion. Over 40 percent of this has been for exploratory and advanced development that is grouped by areas of technological disciplines, although it also includes the basic work leading to new systems.

There is a difference between the level of detail congressional authorizing committees

[35] Once two of the most promising candidates explored through annual funding have been selected for prototype demonstration, contracting for the full demonstration and test phase would be appropriate. Such a phase may require longer than one year.

[36] "The fact that one does not need to make decisions in the face of major uncertainty but can instead take steps to reduce uncertainty is an essential quality of the development process. . .

"Where there is great uncertainty about the ultimate value of the developed product or where a large state of the art advance is being sought, strategies that emphasize sequential decisionmaking are generally more attractive than those that do not." T. K. Glennan, Jr., note 7, *supra*, pp. 18, 45, 47.

[37] See T. Marschak, "The Microeconomic Study of Development," in Marschak, et al., *Strategy for R&D*, p. 8.

TABLE 3. DOD'S PROPOSED FISCAL 1973 RDT&E BUDGET BY R&D CATEGORY[a]

(Millions of dollars)

Category		*Fiscal 1973 program*
Research		351.5
Exploratory development		1,145.4
Advanced development		1,771.0
	Subtotal	3,267.9[b]
Engineering development		2,383.3
Management and support		1,125.9
Emergency funds		50.0
Operational systems development		1,724.7
	Total	8,551.8

[a] Budget as presented for congressional approval.
[b] About $2.2 billion is considered to be technology base activity.
Source: Fiscal 1973 Federal budget.

want to review and what DOD feels is meaningful.

The Chairman of the R&D Subcommittee of the Senate Armed Services Committee has said that the subcommittee—four Senators and one staff man—had to examine $8 billion in R&D money going to about 4,000 projects. He said they were lucky if they could take a look or have a briefing or a hearing on 15 percent of the 4,000 projects.[38] The Chairman of the Senate Armed Services Committee agreed that it was very difficult for Congress to get into it at all.[39]

It is virtually impossible to review and analyze the DOD R&D budget request effectively because:

- There are too many projects.
- The entries generally are not descriptive of the purpose for which the R&D activity is to be undertaken.
- There is lack of clear correlation between most of the projects and defense needs.

As a consequence, congressional review is done mainly by exception. For example, if a project's funding is significantly more than it was last year, the increase is questioned. Yet, in other less prominent or provocative projects, the course may be set for what later emerges as a major system with a budget of several hundred million dollars to support its final stages of development.

Although the AH–56 Cheyenne helicopter appeared for large-scale funding in 1965, it began years earlier in exploratory development under a project titled "aircraft suppressive fire." Another project called "air mobility" also helped finance this early armed helicopter exploration. In about 1963, the project was moved into an advanced development project listed as "aircraft suppressive fire" and in 1964 became an engineering development activity identified as the "aircraft suppressive fire system." This was changed later to "weapons helicopter" and still later to the "advanced aerial fire support system." With each change, the identifying project number was changed.[40]

Although these funds were small, they were financing the activities leading to a Qualitative Materiel Requirement (QMR) being approved by Army headquarters in 1965. Among the work paid for was a system concept study by the Planning Research Corporation in 1964 and industry concept formulation studies between 1962 and 1965, all of which provided information for this requirement document.[41]

To make the exploration of the system even more obscure, essential parts of the Cheyenne (the TOW missile and night-vision avionics) were funded under still different identifying numbers and accounted for separately. There was no consistent grouping of all funds di-

[38] These 4,000 projects are grouped under 369 program elements. Authorization from the committee must be received if more than $2 million is to be reprogrammed from one program element to another. From Weapon System Acquisition Hearings, note 23, *supra*, Thomas J. McIntyre, Dec. 3, 1971, pp. 35–36.

[39] Weapon System Acquisition Hearings, note 23, *supra*, p. 47.

[40] The information was obtained from the Department of the Army with the following statement: "Because of the age of the reference documents containing the . . . information and the nature of [early technical work] the . . . program elements contributing technology to the [Cheyenne helicopter] is undoubtedly not all inclusive."

[41] Letter from the U.S. Department of the Army, Office of the Assistant Secretary, to the Commission, Nov. 20, 1972.

rected toward improving the mission of close air support that were, in fact, being used to explore alternative systems and move toward the Cheyenne.

Because major system programs have been in trouble, one congressional remedy has been to demand more detail regarding early technical expenditures. However, the purpose of such expenditures has a tendency to be obscured by the increased concern with technical detail. As a consequence, Congress is hard pressed to focus on the mission needs being addressed by the major portion of the research, development, and test expenditures of DOD. At the same time, congressional concerns over specific detailed projects tend to reduce DOD's flexibility in exploratory efforts.

In reporting out the defense authorization bill for fiscal 1973, the Senate Armed Services Committee expressed concern that the action taken by DOD to reduce the RDT&E program elements from 475 in fiscal 1972 to 369 in fiscal 1973 would hinder congressional monitorship. The committee recommended increasing the number of program elements for fiscal 1973 by 75.[42]

The services' ability to reprogram R&D expenditures as new technical information becomes available is inhibited by an authorization and appropriation procedure that requires further congressional approval if early technical projects do not proceed as planned or are in danger of exceeding appropriated dollars by a specified amount. Congressional approvals are required even if the purpose of the technical work remains unchanged.

DOD is permitted to reprogram money from one program element to another as the need arises, unencumbered by high-level procedural approval, as long as a program element cost that contains the projects does not exceed its allocation by more than $2 million. The issue here is the relative amount of dollars contained within each program element. DOD believes it should increase, but the committee believes it should be less to give more control over reprogramming. More program elements would further complicate the committee's review and, more importantly, would bring the staff into a level of technical detail that may be unnecessarily complex.

Obviously, a "blank check" approach is not prudent, but the grouping of R&D projects into larger program elements should help *as long as the mission purpose for the program element is clearly identified and understood.* Present funding categories are identified by the kind of technical activity to be undertaken. This causes a reviewer to concentrate ineffectively on technical details rather than on the overriding purpose for the request.

On a congressional level, it would be more meaningful to debate, for example, the relative importance of the fleet defense mission compared to other defense mission areas. It also would be more meaningful to be informed of alternative technical approaches being explored by DOD than to discuss the relative technical performance of various weapon systems. The cost of solving fleet defense mission problems could be related to the cost of solving other mission problems that may have higher or lower priorities. For Congress, an effective approach would be to challenge the purpose of the proposed expenditures. A less effective one would be to challenge the approach taken to meet the purpose.

Technical judgments properly belong to the operating units in the executive branch that are actually managing the work and are therefore more familiar with the technical values of competing or complementary approaches. DOD must make the purpose for which the funds are to be expended clear and advise the committees of the alternatives they are exploring to achieve the purpose.

CONCLUSIONS AND RECOMMENDATIONS

The following current practices pertain to alternative systems:

Technology Base

- Within the technology base, subsystems frequently are developed into fully configured designs independently of a system application. Later, directed use constrains and

[42] U.S. Congress, Senate, Committee on Armed Services, *Authorizing Appropriations for Fiscal Year 1973 for Military Procurement, Research and Development, Construction, Authorization for the Safeguard ABM, and Active Duty and Selected Reserve Strength, and for other purposes*, S. Rept. 92-962, 92d Cong., 2d sess., 1972, pp. 107-108.

complicates the design of candidate systems, limits the flexibility of procurement planning, and causes a narrowing of the technical span of alternatives.

- Technical resources used in improving familiar systems feed "old" technology back into the technology base.

- Use of the present technology base has been characterized by extensions of old technical approaches leading to systems that are less technologically advanced but more expensive and complicated.

- Application of new technology in innovative system approaches can contribute to making systems both more capable and less expensive and can feed back information to expand the technology base.

Creating and Exploring Alternative Systems

- Selection of system concepts and their essential features is done within the Government by development groups that are not challenged effectively. Selections tend toward improving current systems by squeezing more out of current technology. This is done by using multiple information sources and combining the best features of each through a process called "transfusion." This contributes to "goldplated" system specifications.

- Industry does not effectively challenge the Government decision process by proposing innovative systems because the Government customer is already inclined toward refining a predetermined system concept.

- The practice of initially stating inflexible performance requirements or highly detailed design requirements has precluded the exploration of alternative technical approaches and, at times, caused attempts to draw more out of technology than was possible, resulting in large cost increases.

- Premature commitment to a system design causes an early elimination of real alternatives and contributes to later cost growth and engineering changes.

Competition in Exploring Alternative Systems

- Competition in exploring systems is introduced relatively late in the evolution of alternatives, after the system concept and preliminary design have been selected. It is an engineering design competition that:

  Creates "competitive systems" that differ mainly in unessential features, because the technical span between competitive possibilities already has been constricted. This situation invites buy-ins.

  Creates a high cost barrier in the entry of small firms and creates pressures to maintain larger established firms.

  Confuses later responsibility for the product and loses the benefits of design continuity and control.

Financing Alternatives: Congressional Review

- It is difficult to identify the funds that are spent to create and explore candidate systems. Technical activities to support the technology base are not separated clearly from those that support the exploration of system solutions to defense mission problems. This situation is a causative factor in the ineffective review of defense R&D by the authorization committees of Congress.

In summary the practices of creating and developing alternative systems need:

- Alternative technical approaches, to hedge against changes in mission need and the inability to predict the outcome of technical activity.

- A minimum of technical constraints when seeking solutions. Selection of early system ideas should be based on the exercise of judgment using agency mission goals and operating constraints as a standard.

- Flexibility to discontinue, modify funding support, or accept new alternative system candidates as the need arises.

• Explicit competition between alternative systems to motivate competing design teams to seek low-cost but adequate solutions.

• Concentration on solving elemental problems of a system before committing to final system development.

• An initial, limited contractual commitment between the Government and each competing contractor, sequentially increasing Government commitment as evidence of solutions is developed.

• Maintenance of worthwhile competing designs up to selection for final development; a recognition and understanding that only the best alternative will enter production.

Recommendation 3. Support the general fields of knowledge that are related to an agency's assigned responsibilities by funding private sector sources and Government in-house technical centers to do:

(a) Basic and applied research

(b) Proof of concept work

(c) Exploratory subsystem development.

Restrict subsystem development to less than fully designed hardware until identified as part of a system candidate to meet a specific operational need.

Recommendation 4. Create alternative system candidates by:

(a) Soliciting industry proposals for new systems with a statement of the need (mission deficiency); time, cost, and capability goals; and operating constraints of the responsible agency and component(s), with each contractor free to propose system technical approach, subsystems, and main design features.

(b) Soliciting system proposals from smaller firms that do not own production facilities if they have:

(1) Personnel experienced in major development and production activities

(2) Contingent plans for later use of required equipment and facilities.

(c) Sponsoring, for agency funding, the most promising system candidates selected by agency component heads from a review of those proposed, using a team of experts from inside and outside the agency component development organization.

Recommendation 5. Finance the exploration of alternative systems by:

(a) Proposing agency development budgets according to mission need to support the exploration of alternative system candidates.

(b) Authorizing and appropriating funds by agency mission area in accordance with review of agency mission needs and goals for new acquisition programs.

(c) Allocating agency development funds to components by mission need to support the most promising system candidates. Monitor components' exploration of alternatives at the agency head level through annual budget and approval reviews using updated mission needs and goals.

Recommendation 6. Maintain competition between contractors exploring alternative systems by:

(a) Limiting commitments to each contractor to annual fixed-level awards, subject to annual review of their technical progress by the sponsoring agency component.

(b) Assigning agency representatives with relevant operational experience to advise competing contractors as necessary in developing performance and other requirements for each candidate system as tests and tradeoffs are made.

(c) Concentrating activities of agency development organizations, Government laboratories, and technical management staffs during the private sector competition on monitoring and evaluating contractor development efforts, and participating in those tests critical to determining whether the system candidate should be continued.

CHAPTER 5

Choosing a Preferred System

The previous chapter discussed the desirability of initially examining a wide span of system solutions followed by exploring those system candidates which have the best chance of meeting the agency's capability, schedule, and cost goals. This chapter discusses the choice of a preferred system.[1]

Needs and goals of a new acquisition program can be the standards used to eliminate unacceptable system solutions and to eventually choose the preferred one. When they are stated without preconceived systems in mind, creative design groups have the flexibility to explore different concepts, technical approaches, and designs. The further this exploration is taken towards alternative system hardware, the more informed will be the preferred system decision.

Thus, preceding decisions on system alternatives—concept, technical approach, design—strongly affect the scope of choice. Depending on how these decisions were made, the choice remaining can be among systems with different operational concepts, the same concept but different technical approaches, or the same technical approach but different engineering designs.

BACKGROUND

Current DOD policy gives the military services the authority to determine their needs, define and choose systems to meet these needs, and then propose them to the Secretary of Defense for approval.[2]

A development concept paper (DCP) supporting the need for a particular system is submitted to the Secretary of Defense. The DCP discusses alternatives considered and a preferred system choice, and includes a plan to develop the chosen system. The DCP defines the system performance characteristics, its estimated cost, when it is needed, areas of major risk, special testing issues, and the acquisition plan.

Approval by the Secretary and authorization of funds by Congress means that both the need and system solution have been accepted. The military service then can initiate hardware development and test to validate the system chosen at this first secretarial decision point. The next step is to hold a competition and select a contractor who will do the engineering design and development work. Contractors may be selected by evaluating paper designs or prototype hardware or by evaluating some combination of both. The basic technology and the essential features of all designs or prototypes will be similar because these were largely decided during a preliminary design phase leading up to the first agency head decision point.

When initial development (called the validation phase) is completed, the military service again requests funds and secretarial approval to proceed with final development.[3] Approval at this stage means that the selected contractor

[1] "Preferred system" means the system which offers the best chance of meeting the agency's stated need, goals, and operating constraints and, therefore, the one to be committed to final development, production, and planned operational use.

[2] This first formal decision point at the secretarial level occurs at the first meeting of the Defense Systems Acquisition Review Council (DSARC I). U.S. Department of Defense, Directive 5000.1, *Acquisition of Major Defense Systems*, July 13, 1971, p. 2.

[3] *Ibid.*, DSARC II, p. 3.

can proceed into final development and test of the entire system.

Figure 1 shows the current DOD approach to choosing a preferred system.

PROBLEM DISCUSSION

In-house agency activities and contractors explore system approaches and do early design work leading up to a single technical approach to a system. In so doing, the agency has tended to settle on a preliminary design for a system before holding an industrial competition. Specified features may include main system characteristics, key subsystems, and their performance expectations.

As a result, the choice of a system and the writing of its requirements often occurs too early in the R&D process and before meaningful exploration of technical alternatives has taken place. By making an early choice, the agency can qualify sooner for the larger resources that accompany an approved system commitment and save time in the early stages. Conversely, early system selection encourages advocacy of one system as opposed to seeking out competing candidates that will save time and cost later on.

Program experience suggests that the kind of data used to choose a preferred system, the timing of the choice, and the subsequent design latitude allowed have a predictable effect on the outcome of a major system program.

Systems that were chosen early and followed by short-lived industry competitions to select contractors to develop them invariably led to design constraints, divided product responsibilities, inflexible contractual arrangements, and later procurement difficulties. Technical latitude was limited to the system the agency had already defined. Awards were difficult to decide, often contentious, and sometimes protested. The price, performance, and schedule commitments obtained from the competitions could be no better than the information used initially to choose the system.

In some cases, the low-confidence nature of the early system choice was recognized by retaining flexibility to change system requirements as development proceeded. Typically, these systems were of such magnitude that it was not practical to have individual contractors compete for their entire development and to transfer total system responsibility to one firm through a contract award. The programs were also a high priority; thus, they could attract large amounts of agency resources, strong program management staffs, and the best talents from industry and Government to solve major technical problems.

The acquisition programs that permitted divided product responsibility and imposed design constraints and inflexible contractual arrangements are the ones that have drawn the most criticism. Succeeding sections of this chapter will discuss in more detail the two methods used for early system choices and the rationale for choosing major systems based on more substantive competition.

DOD APPROACH TO CHOOSING A PREFERRED SYSTEM

		DSARC I	DSARC II
AGENCY HEAD	Monitors	Approves	Approves
MILITARY SERVICES	Establish system requirements; choose system and characteristics generally without competitive exploration	Prove out system concept through contracted paper studies or hardware	Initiate final development

Source: Commission Studies Program.

Figure 1

Early System Choice

Several factors motivate an agency to choose a system early. A military command may have established an inflexible date for a new system to be operational. This time pressure encourages early choice in order to proceed into full-scale development.

To explore different system concepts and introduce competitive development requires R&D money of a scale usually not made available until a decision[4] has been reached that a given system approach should be pursued, something of a paradox. At that point, the military service has submitted a DCP to the Secretary of Defense. Approval carries a commitment to specific performance, cost, and delivery conditions. Thus, under the present process, the surest way to obtain significant allocations of R&D funds is to commit to a system. Following the intra-agency commitment, the head of the agency becomes committed to Congress when seeking authorization and appropriation for the prospective system. Then everyone (the contractor, the agency component, the agency, and Congress) is locked-in to the one system approach.

When an early choice is made, the ensuing development is entrusted to a single contractor and the risk of failure is increased for the agency as well as the contractor. This commitment to an unchallenged, still unproved single system causes the establishment of redundant checks and balances because there are no alternatives and because enormous public monies are involved.[5] Multiple checks over sole-source contractors result in a proliferation of in-house staffs, procedures, regulations, and layered decisionmaking, all of which are mirrored in the cost of industry contracts.[6]

TRANSFER OF PERFORMANCE RESPONSIBILITY FOR AGENCY-DEFINED SYSTEMS THROUGH CONTRACT AWARDS

In most cases, responsibility for performance of systems defined by an agency component is transferred to industry through contract awards. Illustrations of such transfers are the Landing Helicopter Assault ship (LHA), SRAM missile, Cheyenne helicopter, the initial Mark 48 torpedo, and the F–111, C–5A, F–14, S–3A, F–15 and B–1 aircraft. In these cases, the system choice and its technical approach were decided based on feasibility studies and other inputs from industry and Government laboratories. Performance specifications were determined by the agency, included in a system description, and sent out to industry for a formal system competition.

Agency requests to industry for proposals to win these contracts averaged 1,000 to 2,000 pages and each contractor's response ranged between 15,000 and 30,000 pages.[7] Final industry competitions usually lasted only about six months, but were intense. The competitions were expensive both to the agency and to the contractors. One contractor, for example, spent $25 million more than he was reimbursed to compete for (and lose) the F–15 competition.

To illustrate the cost of these competitions, in the case of the B–1 program the Air Force spent $140 million on feasibility and other studies during the period 1965–1970 to write the development specification. Seven companies spent $66 million while preparing and waiting for receipt of the request for proposals. It cost five companies a total of $36 million in company funds. In sum, it cost nearly one quarter billion dollars to prepare for B–1 competition, to prepare the proposals, and to await the source selection decisions.[8]

In most cases, requests for proposals specified that technical factors would count the most in competitive evaluations. However, price eventually became the primary consideration because of "technical leveling" of con-

[4] *Ibid.*, DSARC I.

[5] For further details see Chapter 6 on program management.

[6] Although vast sums are involved, it is not possible to quantify the cost of these monitoring efforts within the executive branch and industry. Estimates range from hundreds of millions to several billion dollars annually.

[7] One program proposal to the Air Force for the Airborne Warning and Control System contained 26,000 pages and involved 1,600 people in its preparation. A proposal on the Navy's Harpoon program was 35,000 pages long. Printed proposal material submitted by the three airframe and two engine contractors in the C–5A competition totalled 240,000 pages. To evaluate these proposals, Government source selection review teams of 200–300 men were not uncommon. Study Group 12 (Major Systems Acquisition), *Final Report*, Jan. 1972, vol. 1, p. 398.

DOD and NASA have taken a number of actions to minimize the material required in the source selection process. A revision of DOD Directive 4105.62, *Proposal Evaluation and Source Selection*, is in process.

[8] Logistics Management Institute, *Contractor Costs During Proposal Evaluation and Source Selection, B–1 Program*, LMI–Task 71–2, Aug. 31, 1971.

tractors' proposals (transfusing the best ideas of each to all the others prior to and during source selection) and general knowledge of the total funds budgeted for the system. With regard to the realism of some of the offers and their acceptance, a top DOD spokesman said:

> Even though the DOD knew or could reasonably have known that the bids were unrealistically low, the Department accepted the contractor's bid and made no effort to determine whether or how the contractor would be able to cover estimated and probable costs that were clearly going to be in excess of bids. As a result of this, we implicitly agreed to either see companies go into bankruptcy or else that we would cover the increased cost through one device or another in the future.[9]

According to the Comptroller General's analysis of one program:

> The winning contractor reduced its ceiling prices about $400 million during the final competitive negotiation based on a reassessment of development risks. There was no change in the required contract performance . . . the scope and circumstances of the price reduction may very well be indicative of an unrealistically low price . . . pressure to pass on cost growth to the Government may be expected to develop.[10]

When contract expenditures on these systems ultimately exceeded the unrealistically low prices bid, the contractor and the Government had to find ways to meet the increased costs. Several alternatives were available but none of them were particularly satisfactory:

- Reduce the performance requirements of the system
- Reopen the contract through engineering changes
- Buy fewer systems
- Transfer money from other programs
- Slip delivery schedules
- Defer or delete test requirements
- Buy fewer spares or other kinds of support items.

As systems proceeded through development and production, engineering changes often accumulated by the thousands. The agency found it had little choice but to accept the changes, which usually delayed schedules and increased costs.

The higher cost risk assumed by the contractors on these programs was not compensated for by higher profits or increased freedom of operation. The agency itself was not satisfied with its control of programs. By the 1970's disillusionment with major system contracting was widespread.

SYSTEM PERFORMANCE RESPONSIBILITY RETAINED BY AGENCY

By contrast, when the "associate contractor arrangement" [11] has been used in early system choices, the agency retained the system performance responsibility. Because the same activity that defined the total system (the agency) was responsible for its performance and the interworking of subsystems, there was more flexibility to change than there would have been if the responsibility had been formally transferred to industry through a contract award. This added flexibility meant that associated contractors had greater freedom for innovation and exploration of technical alternatives on a subsystem and component level.

In some cases the agency's program office played a strong role by having advanced development of subsystems tailored to the system and managed from the outset by the program manager. This meant that engineering boundaries between subsystems were drawn in such a way that conflicts among them were minimized when integrated into the system.

Agencies have managed a few high-priority programs this way. The Apollo and Polaris programs are examples. As previously noted,

[9] U.S. Congress, House, hearings on DOD Appropriations, FY 73, statement of former Deputy Secretary of Defense, David Packard, part 3, pp. 216–217.

[10] U.S. Comptroller General, Report B–168664, *Analysis of the F–14 Aircraft Program*, Aug. 17, 1970, pp. 52–53.

[11] In the associate contractor arrangement, the agency is responsible for managing technical relationships among the associate contractors and for maintaining overall technical surveillance of the program. The agency thus performs a role similar to that of a prime contractor in system engineering and design.

the agency defined the system preliminary design and some key subsystems on such programs as the F–111, C–5A, F–14, and F–15 aircraft but contracted out the detailed design and, with it, performance responsibility to individual industrial concerns. In such cases there was actually divided responsibility for design of the system product.

When the agency retained the system performance responsibility, its ability to change technical direction was facilitated because these programs often arose suddenly from a high-priority need or a new technical opportunity. As a result, few people had preconceived notions as to what the system should look like, how it should operate, or what its technical performance characteristics should be. In such instances, the agency assembled a strong technical organization of its own, and sought multiple approaches to problems from the best sources in and out of Government.

Major programs carried out in this manner were sometimes assisted by close collaboration among top executives of the agency and contractors to make available specialized research facilities and to combine the efforts of their experts in such a way as to increase the likelihood of a scientific and technological breakthrough.

Important to an early choice of a very uncertain system concept and technical approach is the selection of a contractor whose technical, managerial, and physical resources are best suited to the contemplated program tasks. The rationale for using contractor capability as a prime selection criterion is that commitment of the capabilities and resources of a specific contractor team has a major influence on program success if a competitive demonstration phase must be bypassed.

Criteria for bypassing a competitive demonstration phase in choosing a new system might include urgency of a need, large-scale resources required to develop competing systems, and only one viable, if yet undemonstrated, system approach.

Choosing a Preferred Major System Through Competition

As noted at the beginning of this chapter, DOD usually chooses a system based primarily on contractor and in-house study information. In the 1960's, the chosen system was then contracted out to industry for final development and sometimes production (total package procurement). A trend of the early 1970's is to first prove out the chosen system by building partial or complete prototypes. In either case, choice of the technical approach and essential characteristics of a system is still being made before a competition takes place. Introducing industry competition after the system has been delineated and when large-scale commitments for prototypes have to be made limits competitor responses as to technical approach and costs, and confines industry participation to major firms.

Financing small design teams during the early evolution of system concepts is not expensive from a total cost viewpoint. To carry design teams further into a demonstration of critical system features requires larger investments of R&D funds. However, investments for even full prototypes may not require more than five percent of the total investment in a program.[12]

These extra costs to explore a wider span of system solutions and broaden competition can have beneficial leverage effects of large proportions on ultimate system performance and on the remaining 95 percent of program costs. Because the full benefits do not manifest themselves until years later, it is difficult to justify such R&D investments at an early stage.[13]

Looking at the past and to the future, no new programs automatically can or cannot afford competitive demonstration as a basis for choosing a preferred system. It is deceiving to say

[12] "The cost of prototypes, on those systems that went into production . . . has been small (2 percent), particularly when viewed in relation to total program or life-cycle costs." Defense Science Board, Task Force on Research and Development Management, *Final Report on Systems Acquisition*, July 1969, p. 63.

[13] "This desire to restrict competition is not limited to Western Europe. This disease can also be found thriving in Washington, D.C. Many economists and politicians will stand up and make strong speeches about how America is great because of its freedom of enterprise and competition. Many of these same economists, bureaucrats, and politicians will return to their daily work and engage in actions which are highly in restraint of competition, and usually on the assumption that a *competition costs money*—and lots of money—and that *we can no longer afford competition*. It seems to me that in most circumstances they could not be further from the real truth." [Italics added] George S. Schairer, *The Role of Competition in Aeronautics*, The Wilbur and Orville Wright Memorial Lecture of the Royal Aeronautical Society, London, England, Dec. 5, 1968, pp. 36–37.

from the outset that any systems that might meet an agency need must of necessity be big and expensive and, therefore, not amenable to demonstration of critical hardware. The "necessity" for bigness comes about mainly because of familiarity with the scale and scope of past systems used to meet comparable agency needs. With a wide range of system candidates and technologies to consider, smaller and less expensive systems have a chance to be brought forward.

The adverse effects of early commitment to a single-system approach could be alleviated with resultant lower overall program cost if several design teams were allowed to follow different technical paths in the innovative phase of system acquisition. The agency might then select one, and preferably two, for competitive demonstration of either critical parts of the system or of a full prototype. Phasing acquisition programs in this manner would provide important benefits lacking in the current process, for example:

- Design continuity from origination of concept through proof of concept
- Differing competitive performance and cost solutions
- Clear contractor product responsibility for a system
- Avoid the risk of a major loss in capability and money if one system selected early fails.

Competitive exploration of technical approaches will produce distinguishably different system performance characteristics. Technical differences should then become a more important criterion for choosing systems and contractors than in the past when differences mainly involved design detail and when an uncertain cost became overly prominent in making awards.

In addition to price, products can create qualitative differences by offering more *utility* in satisfying the buyer's need. The increased utility can involve such things as reliability, longer life, and ease of operation and maintenance. These advantages are important to the buyer because often his operating and maintenance costs eventually will exceed an initial acquisition price several fold.

System Choice Based on Mission Performance and Ownership Cost

Mission performance level, that is, the ability of a new system to provide needed mission capability in an operating environment, can be the standard used to measure competing systems with different performance characteristics. Measuring systems by comparing price alone does not provide a conclusive standard and the choice may not satisfy the required mission capability or may satisfy it only marginally.

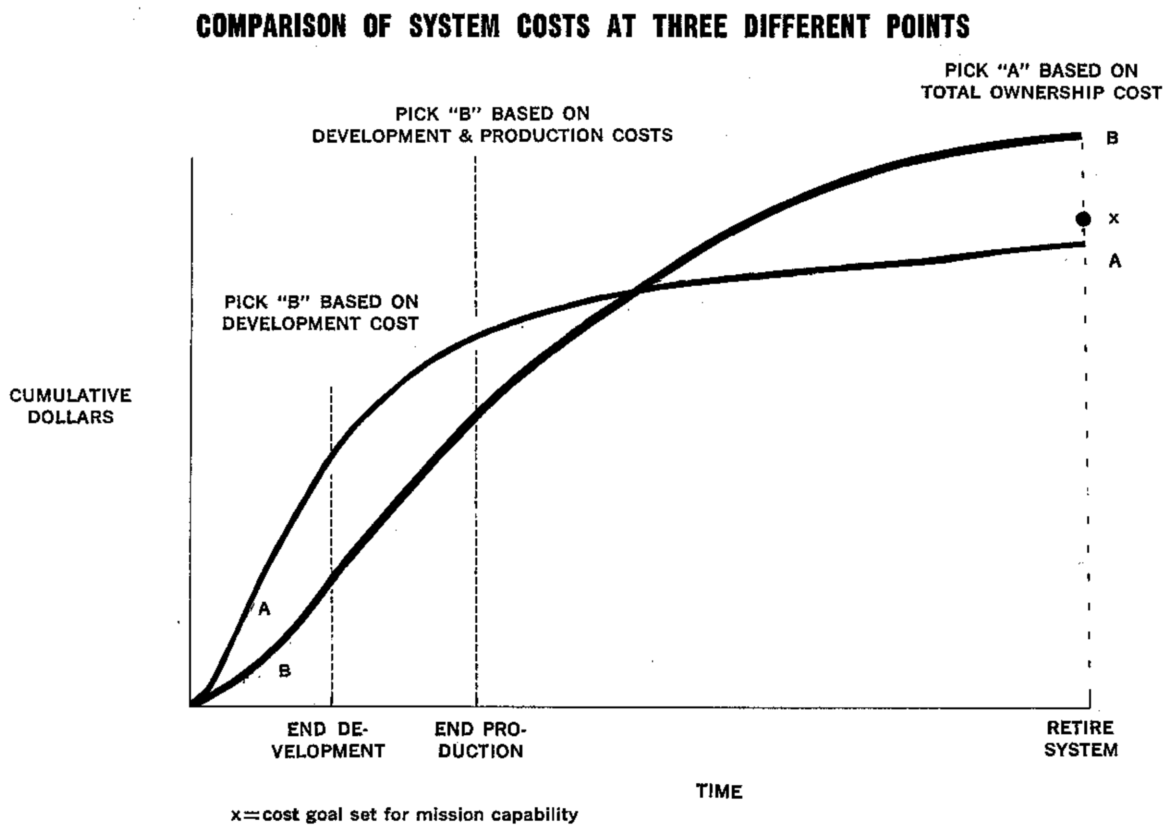
Different systems with substantially different features and performance characteristics can fulfill the same mission capability. These differences will result in widely different costs to the buyer. For example, system A to be used to attack enemy targets could have four times the accuracy of system B, but both could provide the same mission capability if a larger quantity of the less accurate system were procured. A simple comparison of the unit prices of systems A and B would not reveal the difference in total cost the buyer will eventually have to pay. The same analogy is true with respect to a differing vulnerability of two systems to enemy defenses.

Figure 2 shows the possible consequences of failure to consider costs of ownership for a particular mission capability.

Assuming that the mission capabilities provided by quantities of systems A and B are equal, and that the time period of their use ends at the point shown, lifetime ownership cost should lead to a choice of system A, although a choice based on initial procurement cost would lead to a choice of system B. This is simply a case where the apparently less costly product will actually cost more in the long run because it has to be replaced more often and is more expensive to operate and maintain.

There are two main objectives of lifetime ownership costing in system acquisition: to assure that important costs, even if paid later, are considered in design of the system and its operation and support precepts; and to help the Government make a contract award decision that is the most cost-effective.[14] To help

[14] Logistics Management Institute, *Life Cycle Costing in Systems Acquisition*, LMI Task 69-10, Nov. 1969 (DDC No. AD-699191). A



Source: Commission Studies Program.

Figure 2

accomplish these objectives, Government multidiscipline teams familiar with the intended acquisition need to operate the proposed systems in the field and collect performance, operating costs, and maintenance data necessary to evaluate the system that would achieve the best balance between satisfying the desired mission capability and incurring the least lifetime ownership cost.

If competitive systems have similar overall mission performance levels, ownership cost should dictate the choice. If the reverse situation occurs or if one system is superior to the other in both mission performance and ownership cost, the choice also would be simple. If the competing systems have widely different mission performance levels and ownership costs, then the most cost-effective system would have to be determined before a choice is made. The creation of an environment that uses ownership cost considerations as a design constraint and decision tool is important and has potential for greatly reduced system costs.

COMPARISON WITH DOD APPROACH

Figure 3 contrasts the current DOD approach with the one discussed here of using levels of mission performance and ownership cost for choosing preferred systems from competitive design team efforts.

Test measurements of mission accomplishment and lifetime ownership cost would take much of the speculation and guesswork out of the selection process with respect to choosing a system and a contractor to produce that system. Such test measurements would remove also some of the past difficulties of estimating ownership cost. Past efforts have had to rely on contractor-furnished projections on systems

joint DOD/industry team is currently preparing guidelines for applying the life cycle costing concept to major systems (Department of Defense, *Life Cycle Costing Guide for Systems Acquisition*, LCC-3 (interim), draft, Dec. 1972).

CHOOSING PREFERRED SYSTEM BASED ON COMPETITIVE DESIGN TEAM APPROACH

	ESTABLISHING NEEDS & GOALS Chapter 3	EXPLORING ALTERNATIVE SYSTEMS Chapter 4			CHOOSING PREFERRED SYSTEM Chapter 5
AGENCY HEAD	Approves; set goals	Monitors		Approves	Approves
MILITARY SERVICES	State mission deficiencies without preconceived systems in mind	Identify system candidates	Sponsor design teams to explore system candidates	Select competitive prototypes	Choose system from mission performance and ownership cost data; initiate final development

CHOOSING PREFERRED SYSTEM BASED ON DOD APPROACH

		DSARC I	DSARC II
AGENCY HEAD	Monitors	Approves	Approves
MILITARY SERVICES	Establish system requirements; choose system and characteristics generally without competitive exploration	Prove out system concept through contracted paper studies or hardware	Initiate final development

Source: Commission Studies Program.

Figure 3

yet to be developed and on which little reliance could be placed for contract award.

The additional information provided for the choice of a preferred system should enable the Government to obtain firm commitments for final development and in some instances for initial production. With the emphasis on demonstrated performance and cost of ownership rather than on a predicted price of initial system procurement, the agency would not be as vulnerable to buy-ins. Contractors, in turn, would be encouraged to put forth their most innovative system approaches because their best ideas would not be subject to transfusion into competitors' proposals and resultant contracts would not be auctioned to the low bidder.

CONCLUSIONS AND RECOMMENDATIONS

• Financial and other pressures encourage commitment to a system concept early, although available R&D information is low-confidence in nature and the range of technological choice and innovation is narrowed.

• The early choice of a system has produced acceptable results when:

The agency retained total system responsibility and gave itself options for changes

Cost-type contracts were used for high risk portions of the program

The best talents in industry and Government could be brought to bear on major technical problems.

• To assure accountability in the expenditure of Government funds in the absence of competition, multiple staff reviews, regulations and decision layering have been instituted to control single-source developers. These control activities result in nonproductive costs that are necessary to some degree but cannot be seen or accounted for and do not measurably improve the system product.

• When early system choices were competed for industry award, transfusion of desired technical features narrowed differences between contractors. This allowed source selection processes to rely on proposed prices at a time of great technical uncertainty.

• The resulting procurement environment has been clouded by buy-ins and contentious awards and with contracts that were subject to so many changes and claims as to invalidate the integrity of original contractual arrangements.

• The information available for choosing a system has been inadequate. Extensive test and evaluation data and other information relating to mission performance measurements and the cost of owning the system during its lifetime have not been developed to a credible level and have not been used as a basis for choosing a preferred system and contractor.

Recommendation 7. Limit premature system commitments and retain the benefit of system-level competition with an agency head decision to conduct competitive demonstration of candidate systems by:

(a) Choosing contractors for system demonstration depending on their relative technical progress, remaining uncertainties, and economic constraints. The overriding objective should be to have competition at least through the initial critical development stages and to permit use of firm commitments for final development and initial production.

(b) Providing selected contractors with the operational test conditions, mission performance criteria, and lifetime ownership cost factors that will be used in the final system evaluation and selection.

(c) Proceeding with final development and initial production and with commitments to a firm date for operational use after the agency needs and goals are reaffirmed and competitive demonstration results prove that the chosen technical approach is sound and definition of a system procurement program is practical.

(d) Strengthening each agency's cost estimating capability for:

(1) Developing lifetime ownership costs for use in choosing preferred major systems

(2) Developing total cost projections for the number and kind of systems to be bought for operational use

(3) Preparing budget requests for final development and procurement.

Recommendation 8. Obtain agency head approval if an agency component determines that it should concentrate development resources on a single system without funding exploration of competitive system candidates. Related actions should:

(a) Establish a strong centralized program office within an agency component to take direct technical and management control of the program.

(b) Integrate selected technical and management contributions from in-house groups and contractors.

(c) Select contractors with proven management, financial, and technical capabilities as related to the problems at hand. Use cost-reimbursement contracts for high technical risk portions of the program.

(d) Estimate program cost within a probable range until the system reaches the final development phase.

CHAPTER 6

System Implementation

After a preferred system solution has been chosen, it must go through final development and production, and then be put into operational use. These are the basic elements of the final phase in the acquisition process. Agency functions involved in carrying out system implementation are: cost estimating and funding; test and evaluation; contracting; and program management.

Aspects of these functions have been discussed in previous chapters. Discussion of congressional aspects of cost estimating and funding began in Chapter 3 (Needs and Goals for New Acquisition Program). In Chapter 4 (Exploring Alternative Systems), the functions of program management, test and evaluation, and contracting emerged. An agency's use of all four functions in choosing a preferred system was covered in Chapter 5. In this chapter, additional aspects of these functions are discussed as they relate to system implementation.

The effectiveness of the implementation phase depends on how well the earlier acquisition phases were accomplished. When the earlier phases are not conducted well or are not done, a tremendous burden is placed on functions carried out in the implementation phase.

In the past, when poor results were obtained from acquisition programs, remedies usually were applied in piecemeal fashion to the late phases of contracting and implementation functions. An underlying theme of this chapter is that remedies applied to the final phase of the acquisition process have been largely ineffective and, in some cases, have themselves unduly complicated the process.

COST ESTIMATING AND FUNDING

Because of the repeated pattern of major cost increases in system acquisitions, many people have concluded that there is need for better cost estimating and better risk analysis. However, improved estimating techniques can bring only relatively small improvements. About 15 percent of cost growth in major programs during the 1960's can be attributed to the inherent imprecision of present cost estimating procedures.[1] Better cost control will come only if fundamental changes are made in the way systems are defined and chosen early in the acquisition process; these steps largely determine ultimate cost and performance.

Entire system costs cannot be estimated realistically during its early development. Institutional arrangements and advocacy pressures tend to drive cost estimates downward and to produce overly optimistic schedule and performance appraisals. All levels in a department, in industry, and even in Congress can become parties to the "selling" of programs founded on unrealistic and unattainable system cost goals. From observations made in earlier chapters, six principal reasons for avoidable cost increases can be cited:

- *System advocacy and premature commitment.* System selection occurs prior to consideration of competing alternative approaches, in order to obtain the funds necessary to proceed with the acquisition program. This choice occurs too early to identify uncertainties and to predict costs.[2]

[1] Perry, Smith, Harman, and Henrichsen, *System Acquisition Strategies*, R–733–PR/ARPA, June 1971, p. 16.

[2] This point is addressed throughout the report, most particularly in this chapter and in chapters 4 and 5.

• *Misuse of price competition.* An intense, "winner-take-all" competition frequently occurs before a design is known to be a satisfactory solution to a need. Technical innovation in competing proposals is inhibited by a predetermined technical approach that makes the competition depend too heavily on the price one company proposes as compared to another. The winner is selected with little assurance that he can meet his quoted price. This form of competition encourages "buy-ins." Buy-ins are difficult to avoid. It is very awkward, for example, for a Government contracting official to counter a too-low offer with a much higher price.[3]

• *Overlapping development with production.* Committing to extensive production when much development, test, evaluation, and redesign still remain to be done usually leads to major retrofit and modification costs. Components, equipment, and tools can be made obsolete by design changes as the development progresses. This practice, referred to as "concurrency," also causes buildups of large numbers of people at prime contractor and subcontractor levels to handle all aspects of the procurement. This early buildup usually comes before a system is ready for full-scale (final) development and major production.[4]

• *Demands for unachievable performance.* Attempts to achieve technical and performance requirements, not validated through early development efforts, often lead to unexpected technical difficulties and related cost increases. The technology base may not be adequate or the required technical development cannot be accomplished within the scheduled time and cost limits. Further, when portions of the system's design originate from multiple industry and Government sources (transfused design requirements), no single organization undertaking system responsibility may have the technical knowledge needed to determine if the specified performance is achievable or if cost and schedule are compatible.[5]

[3] Chapter 5.
[4] See Test and Evaluation, *infra*.
[5] Chapter 4.

• *Demands for increased performance within present technology.* Demands for increased performance capabilities over previous systems have been a principal factor in the growth of new system costs.[6] When new capabilities depend on squeezing more performance out of existing technology, the result usually is increased complexity and disproportionately higher cost.[7]

• *Sole-source development.* When a decision is made for a single system solution rather than to pursue competing approaches, the contractor selected at the outset becomes a sole-source developer and producer. Without the challenge of competitive alternatives, cost control is problematical and some complacency inevitably develops.[8]

Background

Initial cost estimates for major systems are based on many uncertain elements. Nevertheless these estimates are used to plan future defense system force levels, to request funds from Congress, and to evaluate contractors' proposals.

Initial estimates tend to stay with a system and influence subsequent estimates and evaluations. As development progresses, many of the initial estimates prove to be too low. Planning and budgeting submissions are usually not adjusted for initial low estimates, however, and budget "reviews" may cause some initial estimates to be reduced further. As a result, major cost increases (often described as "cost overruns") commonly emerge during the final development and production phases. For example, the estimated cost to complete 77 DOD

[6] The Deputy Director, DDR&E recently underscored this: "In reality, the true increased costs of weapons systems have been driven by demands for more performance. For example, we believe the components of increased cost—payload, range, speed, avionics, accuracy, crew safety—have been the dominant factors in causing weapons systems to increase in cost over any given time period. Of course, decreased production, increased paperwork and inflation have also helped to drive costs upward. It is clear to us that alleged DOD mismanagement of weapons systems cost estimating has not been the dominant factor in cost increases. Abuse of the 'requirements' process is the more likely culprit." Armed Forces Management Association—National Security Industrial Association Symposium Proceedings, *Cost—A Principal System Design Parameter*, Aug. 16–17, 1972, p. 20.
[7] Chapter 4.
[8] Chapters 5 and 6.

major systems, as of June 30, 1971, exceeded the original planning estimates of $94 billion by about $28.7 billion.[9]

The term "cost overrun" has been part of the contracting vocabulary for years. "Cost overrun" originally meant that a contractor's actual expenditures under a cost-reimbursement type contract exceeded the estimated cost initially established in the contract. When this occurred and if the Government wanted the contractor to continue, additional money was added to the contract. This money was used to reimburse for the overrun only; the fixed fee was not changed.

In the 1960's the term "cost overrun" came to be applied indiscriminately to all types of contracts and now connotes poor estimating, bad management, or inept contracting. Because of the derogatory implications of the "cost overrun" label placed on any increase in contract costs, DOD adopted a noncritical, explanatory term, "cost growth." Although cost growth is now used officially to describe all increases,[10] it has not replaced the popular term "cost overrun." The term persists because some part of a major cost increase is avoidable and thus deserves critical attention.

[9] U.S. Comptroller General, Report B-163058, *Acquisition of Major Weapon Systems*, July 17, 1972, p. 36.

[10] DOD has established various categories for classifying cost increases on major systems including changes in system characteristics, quantity, delivery date, wage rates or material costs tied to changed economic levels and additional support items and unforeseen and uncontrollable events.

Problem Discussion

Serious cost estimating and funding problems surfacing in the system implementation stage are the inevitable result of shortcomings in the earlier phases of acquisition programs. For example, when system design features originate from multiple industry and Government sources and the system is selected before development begins, there is little chance that any one organization taking system responsibility knows whether desired performance is achievable or what it will cost.

Table 1 compares two methods of committing to a system: a conglomerate design approach; and an approach predicated on allowing competitive design teams to proceed through early critical development phases before making a system commitment.

Realistic cost estimates for new defense systems, together with future fiscal guidelines, are necessary to plan availability of chosen systems for defense force levels. When these

TABLE 1. COMPARISON OF TIMING AND METHOD OF SYSTEM COMMITMENT

Method	*Advantages / Disadvantages*
1. Early system commitment based on combining proposed design features from multiple industry and Government sources	*Advantages* • Initial cost of exploratory development is minimal • Permits earlier commencement of full system development. *Disadvantages* • Technical unknowns are unresolved • Unstable estimates and funding • Restricts technologies to design "givens" • Encourages "buy-ins" • System quantities to be procured (planned military force levels) subject to disruption.
2. Later system commitment based on competitive design and demonstration efforts	*Advantages* • Competition operates during early innovation phase • Hardware test data available for estimating and budgeting requirements • Little incentive for buy-ins • Establishes product and cost responsibility • Alternatives may provide less expensive systems • Military force levels determinable. *Disadvantages* • Higher initial cost of competitive exploration and test • More time required in early phase.

Source: Commission Studies Program.

systems ultimately have to be funded at substantially higher amounts than originally planned, severe reductions in planned force levels occur. This force level implication of early system commitment will be developed further in this chapter.

THE COST ESTIMATING DILEMMA

Realistic cost estimates are indispensable to an agency for exploring, evaluating, and selecting a new system; to Congress for appropriating program funds; and to procurement officials for negotiating contracts. DOD customarily classifies cost estimates as:

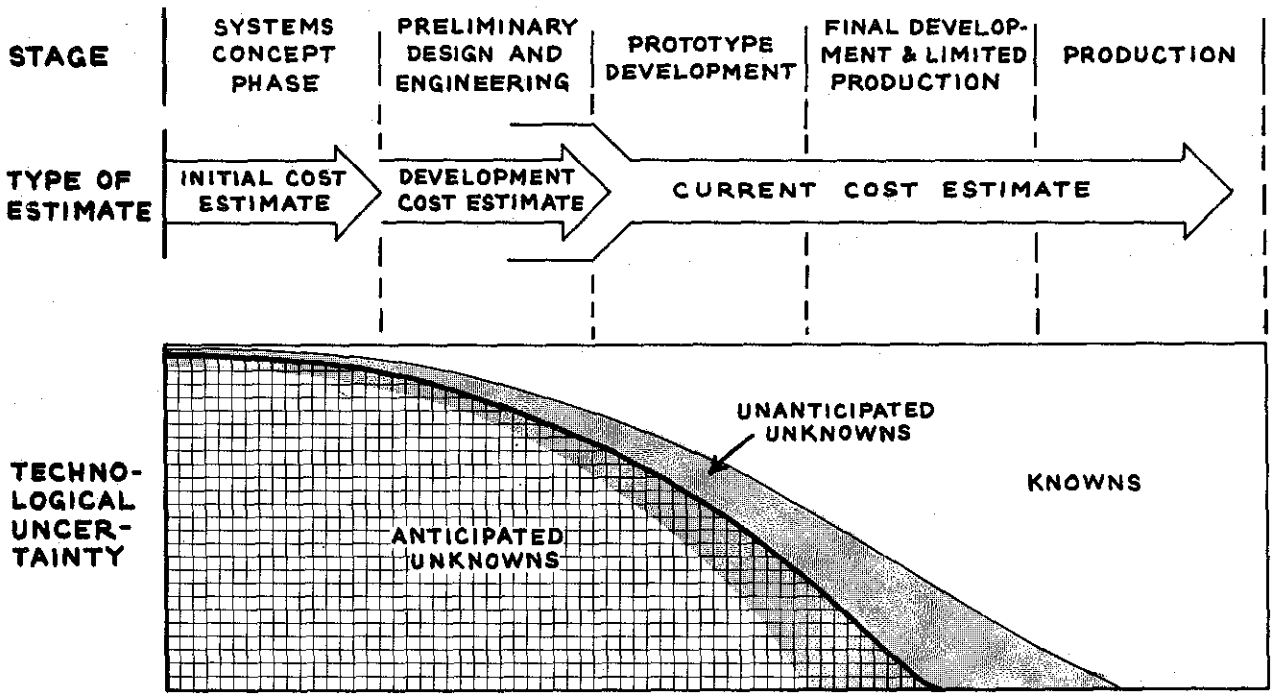
- Planning estimates—the initial program estimates
- Development estimates—refined predictions made during the preliminary design and engineering period
- Updated estimates—current estimates of the cost of acquiring total programs, adjusted as changes occur in the later phases of a program.

These three categories are shown in figure 1 as they relate to a decrease in technical unknowns.

Unanticipated unknowns begin to emerge in the early design phase and increase thereafter because major system programs usually require significant concurrent advances in technology for subsystems (for example, propulsion, hydrodynamics, and electronics). At the outset, technological risks are great; a large number of the technical problems that

MAJOR SYSTEM ACQUISITION

RELATIONSHIP OF COST ESTIMATES TO DEGREE OF TECHNOLOGICAL UNCERTAINTY AT VARIOUS STAGES OF A MAJOR SYSTEM



Source: Commission Studies Program.

Figure 1

must be solved can be identified, although solutions are not known. These are the anticipated unknowns that the initial cost estimate must cover. The reliability of an initial estimate is made even lower because unanticipated problems, so-called "unknown-unknowns," inevitably arise during development. Cost estimates become more reliable as work progresses through the stages of preliminary design, prototype, final development, and production.

During the first part of the study phase of an acquisition, several alternative technical approaches are examined. Available technology is assessed, experimental hardware may be developed and evaluated, and plans are reviewed and reassessed on the basis of technical risk, cost, and timing. Many gross, "order-of-magnitude" estimates are made during this stage, usually with cost and performance data furnished by prospective contractors. These estimates are used in planning and in considering the relative merits of alternative approaches. Cost estimates may be deflated or overly optimistic as a result of competition for funds among the services and their components. Competition exists among programs intended to fulfill the same organizational missions and between proposed new programs and ongoing programs. Each agency component must "sell" its programs in order to maintain or enhance its capabilities and future status.

If the initial operational capability (IOC) date is treated as an imperative deadline, the study, development, and production phases may be compressed to force a program into final development or production before it is ready, thereby magnifying the impact of uncertainties on costs.

Acquisition planning often has relied on cost and schedule estimates prepared by advocates of a proposed new system. The advocates understandably tended to minimize unknowns and defer the resolution of uncertainties to later stages. The process has lacked an impartial and consistent review mechanism for evaluating the realism and validity of estimates and deferred risks.

This cost-estimating process was characterized in congressional hearings as follows:

> Decisions are not likely to be much better than the information and analyses on which they are grounded. In weapon development program decisions, most of the information on costs, schedules and detailed technical performance expectations originates with the contractors. Obviously, contractors have reasons to present their prospective programs in a favorable light; they tend to be optimistic. On its way to the apex of the defense decision-making hierarchy, this information passes through what organization theorists call 'filters'—the program management offices of the military services and high-level military staff units. Organizational filters could conceivably serve to correct initially inaccurate information inputs, but in the present context, the military involved are, themselves, advocates, so they often fail to make the corrections.[11]

Based on these optimistic premises, programs usually are budgeted according to early estimates with no substantive provisions for contingencies. Rarely have agencies made provisions for work not identified during the definition process, or for funds and time for other contingencies that almost inevitably arise in development programs.[12]

Agency personnel have learned that premature commitment is unavoidable because it is practically the only way to get substantial funds for development work. Participants in a workshop conducted by the Commission agreed that agencies will discourage realistic cost estimates when current agency budgets are inadequate and that this tactic often was sanctioned, if not overtly encouraged, by all levels, including congressional committees.[13]

In this connection, a DOD study and later reports by the General Accounting Office (GAO) and the Logistics Management Institute (LMI) agreed that the cost estimating process could be improved. The GAO review of 18 major systems found examples of both adequate and inadequate application of cost estimating criteria. GAO recommended that the Secretary of Defense develop and implement DOD-wide

[11] Testimony of F. M. Scherer in hearings before the Subcommittee on Economy in Government of the Joint Economic Committee on the Military Budget and National Economic Priorities, 1969, Part 1, p. 385.

[12] An item in the *Washington Post*, Jan. 6, 1972, announced that $5.5 billion was authorized to be budgeted by NASA for the space shuttle, and said: "The White House . . . added a contingency of $1 billion for planning purposes 'because of the highly complex technological nature of the project.' "

[13] See transcript of workshop, vols. I and II, and Study Group 12 (Major Systems Acquisition), *Final Report*, Jan. 1972, appendix 13.

guidance to provide a disciplined cost estimating process.[14]

Starting in January 1972, DOD requires the military services to submit an independent parametric cost estimate[15] when seeking approval to proceed to the next phase of a system acquisition. Each service has created a staff component, organizationally separate from program advocates, to prepare these parametric estimates. A separate DOD Cost Analysis Improvement Group assesses the criteria followed and the reasonableness of the independent estimates.[16]

These DOD actions in cost estimating will improve the system acquisition process. Such improvements, however helpful in these aspects, will not resolve the fundamental problems in the acquisition process. Better initial estimates illuminate likely costs more clearly, but they do not solve the problem of having to fund increasingly more expensive systems.

PROGRAM FUNDING AND IMPACT ON FORCE LEVELS

Funding begins with the allocation of research and development funds for component and subsystem work and concludes with congressional approvals of major systems during their final development and production phases. As noted, initial program estimates historically have been too low and, consequently, programs have been underfunded. Lacking enough money, the agency is often forced to:

- Shift money between programs and sometimes obtain reprogramming authority from Congress
- Obtain higher than planned appropriations from Congress in succeeding years
- Reduce the number of units to be procured and deployed (force levels).

The last noted remedy—reducing force levels—has caused increasing concern. For example, the Chairman of the Senate Armed Services Committee is quoted as saying:

> At these stratospheric price levels, there has been a tendency in the Pentagon to cut back on costly weapon orders—to reduce the numbers of planes to be bought—for example, when costs under a given contract begin to escalate. Our committee has suggested that this sort of backing and filling would leave us with forces inadequate to perform their assigned missions.[17]

Figure 2, based on a sample of defense systems and on the assumption that procurement funds will be available at current levels, shows a shortage of about five billion dollars in procurement funds needed to maintain *planned* force levels for the selected sample.[18]

The trend of declining force levels is expected to continue during the next several years. DOD is currently experimenting with having some new systems designed to a unit cost in an attempt to reverse this trend. If the current trend continues, force levels will decline substantially, reducing available aircraft and armored vehicles, for example, for specific mission needs by almost one half by 1980.[19]

INDUSTRY SUGGESTIONS

The Defense Science Board and the Secretary of Defense's Industry Advisory Council (IAC) have suggested improvements in fiscal planning by including financial and schedule contingencies in budgets for all major system programs.[20] IAC recommended that guidelines

[14] The following nine criteria were considered to be basic to effective estimating: clear identification of task, broad participation in preparing estimates, availability of valid data, standardized work breakdown structure for estimates, provision for program uncertainties (risks), recognition of inflation, recognition of excluded costs, independent review of estimates, and estimate updating. (U.S. Comptroller General Report, B-163058, *Theory and Practice of Cost Estimating for Major Acquisitions*, July 24, 1972, p. 9.

[15] Independent, as used by OSD, means independent of the project office and using data other than that furnished by potential or actual contractors in connection with the program being considered. Parametric has been defined as: "An estimate which predicts costs by means of explanatory variables such as performance characteristics, physical characteristics, and characteristics relevant to the development process, as derived from experience on logically related systems." (Bruce M. Baker, *Improving Cost Estimating and Analysis in DOD and NASA*, an unpublished dissertation, George Washington University, Jan. 1972, p. 106.)

[16] Memorandum from the Secretary of Defense to the Secretaries of the military departments, *Cost Estimating for Major Defense Systems*, Jan. 25, 1972. The Cost Analysis Improvement Group is chaired by a Deputy Assistant Secretary of Defense, Systems Analysis, and has members from DDR&E, Comptroller, Installations and Logistics, and Systems Analysis.

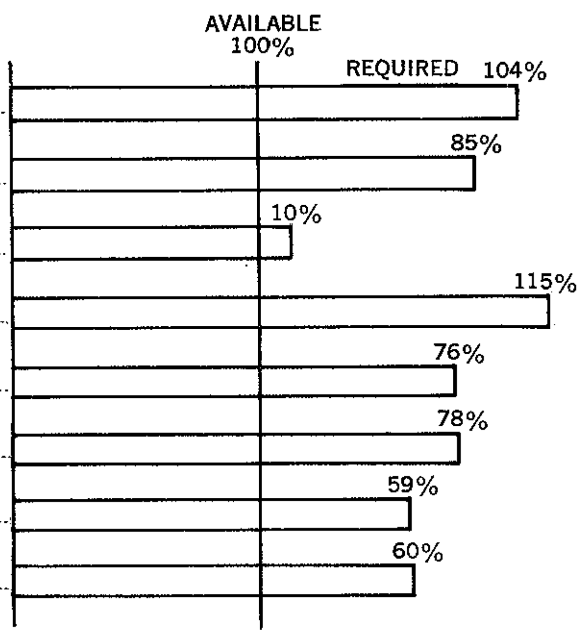
[17] August 1972 Defense Symposium, note 6, *supra*, p. 2.

[18] In many quarters and in DOD itself this is considered to be an optimistic assumption. If procurement funds go below current levels, the impact of systems cost growth on available force levels would be even greater.

[19] August 1972 Defense Symposium, note 6, *supra*, p. 30.

[20] Defense Science Board, Task Force on Research and Develop-

SUMMARY OF "AVAILABLE" AND "REQUIRED" ANNUAL PROCUREMENT FUNDS



(MILLIONS OF DOLLARS)

	TOTAL FUNDS NEEDED	AVAILABLE	ADDITIONAL REQUIRED
ASW AIRCRAFT	613	300	313
ARMORED VEHICLES	461	250	211
NAVY SHIPS	2390	2200	190
ARMY AVIATION	700	325	375
AIRLIFT & TRAINING A/C	352	200	152
TACTICAL AIRCRAFT	4252	2400	1852
OFFENSIVE STRATEGIC	3230	1900	1330
DEFENSIVE STRATEGIC	1567	950	617
TOTAL	13565	8525	5040

Source: Armed Forces Management Association—National Security Industrial Association Symposium Proceedings, Cost—*A Principal System Design Parameter*, Aug. 16–17, 1972, p. 29.

Figure 2

be established for budgeting for unforeseen program costs, including engineering changes.[21] IAC suggested that funding reserves be provided as a matter of course for two reasons:

- *Funding deficiency*, or failure to fund at the time and in the amounts originally approved causes expensive program renegotiation, redirection, stretchout, and growth.

- *Funding insufficiency*, or failure to fund adequately at the outset causes the program to begin with a built-in deficit of 20–30 percent. The budget is based on estimated contract target costs and does not recognize the historical pattern of additional and unforeseen costs as the program develops.[22]

These suggestions assumed that the basic structure of the acquisition process would continue unchanged. They can be interpreted as stating that if it is necessary to commit to a system early (before technical and other uncertainties have been resolved), certain actions may reduce the impact of the inevitable program cost increase.

The need to commit "early" to a system is rare and should not be "normal" practice.

IMPLICATIONS OF PRIOR RECOMMENDATIONS

Table 2 outlines the process being recom-

ment Management, *Final Report on System Acquisition*, July 31, 1969, pp. 7, 19.

[21] Industry Advisory Council, Panel A, *Report on the Major System Acquisition Process*, June 14, 1969, p. 12.

[22] *Ibid.*, p. 8.

TABLE 2. MAJOR SYSTEM ACQUISITION BASIC ACQUISITION STEPS RECOMMENDED BY COMMISSION

	Establishing Needs & Goals	*Exploring Alternative Systems*	*Choosing Preferred System*		*Implementation: Final Dev., Prod., and Use*
Congress	3 Visibility	6 Authorizes R&D funds by mission	13 Authorizes system; appropriates funds		17 Authorizes system; appropriates funds
Agency head	2 Reconciles need; sets cost goal	5 Allocates funds by mission for system candidates	9 Approves	12 Approves	16 Approves production
Agency component	1 Submits needs and goals information	4 Sponsors best candidates	8 Selects system for demonstration	11 Chooses preferred system based on test and ownership cost data	15 Conducts separate operational test
Private sector		7 Designs system alternatives within mission cost goal		10 Builds and demonstrates prototypes	14 Performs final development and limited production

Source: Commission Studies Program.

mended in this report for the more "normal" acquisitions, and shows 17 steps to be taken in the four distinct stages of the process. After a mission need and a cost goal have been established as the first steps, the acquisition process begins.

In the second stage (steps 4 and 7), efforts are made to solve the critical technical problems confronting alternative candidate systems. This sequential effort would be funded by annual contracts with limits on the amounts the Government will pay for the reduction of uncertainty about different solutions.

As system candidates are explored and the most promising ones selected for competitive demonstration, other elements of the system not requiring special development would be integrated so that a prototype might be demonstrated in the third stage (steps 8 and 10). System tests and evaluations would follow to provide data on mission performance measurements and the ultimate cost of owning the system. In the fourth stage (steps 11 and 14), a preferred system would then be chosen for final development and initial production and implementation.

The recommended process is designed to reduce uncertainties in a systematic, efficient progression leading to final development and a limited production quantity.

It is anticipated that the process outlined above would:

- Avoid using early estimates as the basis for planning future force levels, requesting congressional funding, and contracting for a major system
- Encourage competing contractors to design *within a cost goal (worth) of a needed mission capability*
- Preclude commitment to any one system until it has demonstrated critical performance features and cost of ownership is established
- Avoid the high risk of premature commitment to final development—one of the main causes of cost growth.

A comparison of the Commission's recommendations with the present process as they might affect congressional funding procedures is shown in table 3.

If it is necessary to begin final development of a single candidate system before a prototype test and evaluation program is conducted, funding and contracting estimates should not be a single "point" estimate but rather a range

TABLE 3. MAJOR SYSTEM ACQUISITION CONGRESSIONAL FUNDING—COMPARISON OF COMMISSION RECOMMENDATIONS WITH PRESENT PROCESS

	Establishing Needs and Goals / *Exploring Alternative Systems*	*Choosing Preferred System*	*Implementation: Final Development, Production, and Use*
Present process	Congress receives briefings from the Secretary of Defense and Chairman, Joint Chiefs of Staff on mission capabilities of our planned forces. Needs and goals for new acquisition programs are not debated until later when a new system has been defined by the Defense Department and the cost for meeting new mission needs fairly well determined by prior studies and preliminary design work done by and within the agency component. Presently Congress is unable to intelligently review the purpose of some 4,000 projects making up the R&D funding request.	Authorizes system final development funds	Authorizes system production funds
Recommended process	The agency would present, as today, information on mission capabilities and deficiencies. What's new is that an organized review of agency missions would be the basis for examining the purpose for starting new programs *before* monies are expended to explore systems. Also, program goals would be presented in terms of how much new capability would be sought, and approximately what the cost of this capability is worth to the agency and when it is to be introduced into the operational inventory. Thereafter, the RDT&E budget requests would be broken down by mission purpose and funding would be appropriated to either begin exploring new systems to meet newly presented needs or continue system exploration for needs presented with earlier budgets. Other RDT&E funds for (1) technology base and (2) final development of systems already chosen would be separate budget items. This approach would tend to alleviate congressional funding delays with a more meaningful level of control over agency expenditures within which the agencies would have flexibility to manage the uncertain tasks of early systems exploration.	No basic change from present process. Earlier recommendations are intended to provide a higher level of confidence in the information submitted at this point. The agency may not have chosen a particular system when its budget is initially prepared but will have one or more potential systems in the demonstration phase. Reduction in funding delays is likely because Congress would have had an early and ongoing view of the program need (purposes of RDT&E funding) and would not have to address this issue when system development funds are being requested.	No basic change from present process. Earlier recommendations are intended to provide a higher level of confidence in the information available at this point. This higher confidence information would come from a demonstrated system in the final development and testing phases.

Source: Commission Studies Program.

of probable costs with upper and lower limits. Plans would be made according to the probable cost range with necessary contingencies included.

This unusual type of expedited development demands accelerated rates of expenditure and longer term commitments, and should be used only when a capability is urgently needed and the cost of providing that capability is of secondary importance. This type of program requires a highly visible disclosure and approval of the reasons for departing from a more normal progression of system acquisition.

Conclusions and Recommendations

• Some increase from an initial estimate for a major system is almost certain to occur:

Intrinsic errors of estimates can be traced to human fallibility and imperfect information and skills and they cannot be avoided.

Optimism of Government and industry program advocates is inherent. Although optimism is essential to success, it should be compensated for in estimates.

The longer the time period covered by an estimate the more likely the estimate will be unrealistic. External forces can severely affect the cost of a system and should be included in the estimates. Because of inflation and a high degree of technical uncertainty an estimate will invariably be too low.

• Decisions to propose a major system program for congressional approval have often been made before high-risk system features have been resolved and before realistic cost estimates can be made, leading to cost growth.

• Major systems are entering the final development and production phases at costs so much in excess of planned amounts that force levels are being substantially reduced.

• Efforts must be made to strengthen and increasingly use an agency's cost estimating capability. However, these efforts will not materially reduce the incidence of cost increases unless more basic changes are made in how systems are defined, competed, developed, and evaluated.

• To improve estimating and funding considerations, a candidate system should not be selected until alternative systems have been explored competitively within an approved cost goal for the need, and until uncertainties have been narrowed acceptably. Candidate systems should be carried in R&D accounts until one is selected for the final development.

Note: Recommendations which would follow from these conclusions have been stated in Chapter 5 relative to the types of decisions and kinds of information to be used in choosing a preferred system with or without competitive demonstration.

TEST AND EVALUATION

A new system requires testing during development and initial use. Some civilian agencies develop one or few-of-a-kind systems, such as the NASA Apollo spacecraft. DOD, however, is the only Federal agency with extensive experience in procuring major systems in quantity. As test and evaluations are of the utmost importance in a decision to procure new systems in quantity, it is in the military services that examination of the conduct, trends, and problems associated with system test and evaluation is most instructive.

Background

Trial and error is an important part of the normal design process. Planned experimentation with hardware is the most economical and fastest means of developing a good product. Paper studies and theoretical analyses are always based on assumptions and existing knowledge; testing deals with realities, not with assumptions.

DOD has separated agency testing into two types: developmental test and evaluation (DT&E) and operational test and evaluation (OT&E). The primary difference between DT&E and OT&E is in purpose; that is, the kind of knowledge they are intended to obtain. This difference influences how and by whom the tests are conducted.

DT&E is part of the repetitive R&D process of design-test-evaluate-redesign that continues until technical uncertainties and reliability problems are resolved. DT&E is usually a semi-scientific measurement of individual performance against engineering specifications such as weight, speed, payload, and accuracy.

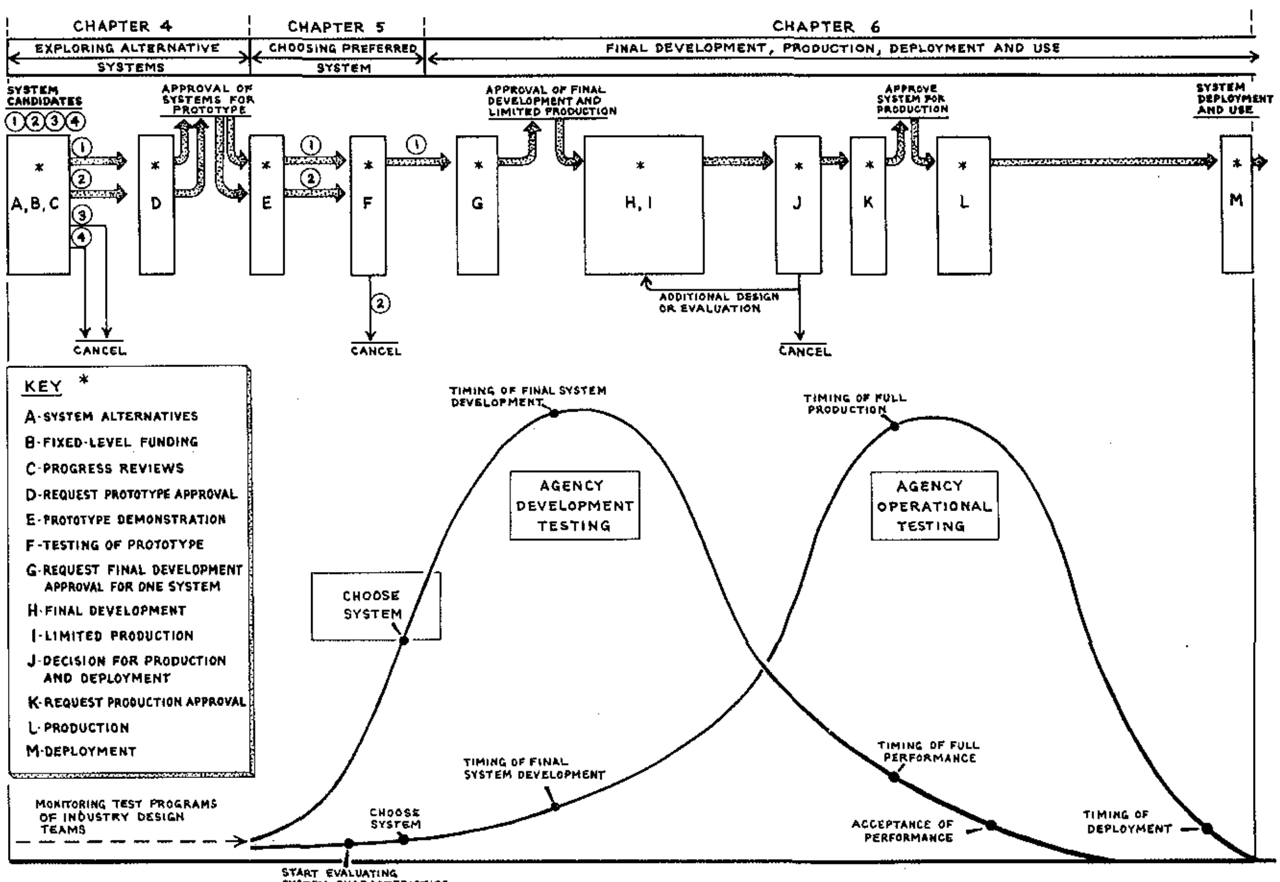
OT&E tests the operational usefulness of a system. This testing gauges how well the system should perform in the expected operational or combat environment, how it should be employed, and whether the system can be operated and maintained effectively by typical field personnel. Figure 3 shows how both forms of testing can support all major system acquisition phases.

At least some limited form of OT&E is necessary as early as possible in a major system program in order to make sure that the engineering specifications, validated through development testing, have operational value. OT&E can be used early, for example, to field test the simulation of a new system feature using parts of old systems.

OT&E after development of a system but prior to production is an important agency test. This testing should be as complete and realistic as possible so that surprises from deployed operational systems are avoided. After full production begins, OT&E continues to identify changes that should be incorporated when a new system is deployed to the user.

Major system programs structured in the 1960's and early 1970's usually had highly compressed development and testing schedules with substantial overlap of production. As a result, the programs were committed to large-scale production before results of critical developmental and operational testing were

RELATIONSHIP OF TESTING AND EVALUATION TO THE SYSTEMS ACQUISITION PROCESS



Source: Commission Studies Program.

Figure 3

known. During this period, major systems typically suffered long and costly schedule delays; many of them suffered further delays from performance, reliability, and maintenance problems in the field.

In the early 1970's, DOD sponsored a number of studies to find remedies for the problems. The studies recommended earlier test and evaluation and the use of test results in key program decisions. Recently DOD has begun reviewing and restructuring system development programs to accommodate earlier testing.

MILITARY DEVELOPMENT TESTING

A large part of DT&E is done by contractors. The objectives range from testing components and verifying design, to demonstrating that subsystems and finally the entire system are "up to specifications." Military agencies acquire developmental test information during early acquisition phases by monitoring and participating in contractor test programs. During final development and initial production stages, however, the agency conducts its own tests on selected subsystems, and the entire system.

To illustrate, a system program office in an Army materiel command oversees the DT&E test program performed by the contractor. Subsequent Army testing of the system is done normally by the Army's Test and Evaluation Command which reports to Army Materiel Command Headquarters.

Similarly, Air Force and Navy system program offices administer contractor test programs, then initiate their own development tests through test centers reporting to their organizational commands. The earliest of these tests is called "preliminary evaluations."

MILITARY OPERATIONAL TESTING

Developmental testing is conducted by technical specialists and scientists; operational testing, however, is conducted by specialists who have operational experience as well. The test objective is to determine how well a system will work in actual operations:

> . . . combat experience suggests that weapons with new and different characteristics are subject to [performance] degradations which are difficult to predict . . .[23]

> Combat [performance] degradation is a phenomenon that may worsen a minor fault in the same way that inaccuracy of a missile in combat is often several times that in test-range demonstrations.[24]

The tension of battle, countermeasures, unfamiliar terrain, and marginal weather are some of the variables missing in the usual development test environment.

At the direction of the Secretary of Defense, the military components have recently modified their testing sequence to require an "initial OT&E" to be reported through operational channels to a headquarters level prior to a production decision.[25] An "initial OT&E" often is an additional function conducted concurrently with normal development tests. A follow-on OT&E is performed on production articles in preparation for operational use.

Each military service is organized differently to conduct OT&E. The Army conducts its OT&E through a number of test boards, including the artillery, armor, and aviation boards. These boards are part of the Army Test and Evaluation Command. This command performs both developmental and operational tests.[26]

The Navy has a separate Operational Test and Evaluation Force (OPTEVFOR) that maintains small test groups and detachments staffed with short-tour individuals having recent operational experience. The head of OPTEVFOR currently reports to the Chief of Naval Operations. In practice, naval surface ship systems have been treated differently from other programs. OPTEVFOR does not test new surface ships or most ship subsystems or their integration prior to fleet introduction. During November 1972, DOD informed us

[23] Capt. Wendell B. Muncie, USN, *Tactical Air Armament Study*, Pt. ii, vol. III, 1970, pp. 21–22.

[24] U.S. Air Force, Hdqrs. Office, Director of Development and Plans, DPN–64–1, *Development Planning Note/Tactical Air to Ground Missiles*, 1964, p. 8.

[25] In response to DOD Directive 5000.1 requiring an operational test and evaluation prior to a production decision. U.S. Department of Defense, DOD Directive 5000.1, *Acquisition of Major Defense Systems*, July 13, 1971.

[26] Following completion of the Commission study, the Army established an independent operational test activity. It is scheduled to be fully operational by Apr. 1973.

that a policy change was being made to reverse the practice.

Air Force OT&E is performed by the particular operating command that will use the new weapon system. The main function of this testing has been to phase the system into the force and develop tactics and training information; thus Air Force operational tests usually have not affected early production decisions over the past decade.[27]

DOD TEST POLICY AND MONITORING

In mid-1971, a Deputy Director for Test and Evaluation was established in the Office of the Director, Defense Research and Engineering (DDR&E). The new office is responsible for policymaking, monitoring, and evaluating developmental and operational testing of the services.

This office now requires each military service to define the critical issues and uncertainties to be addressed during subsequent test and evaluation phases. The results of the tests and evaluations by the services are to be used for major program decisions, including those to begin final development and to begin production.

Problem Discussion

One of the primary findings of our study is that too much is committed on individual major system development and production before ideas, needs, designs, and hardware are tested and evaluated. Agency testing usually has come so late that the opportunity to use the information effectively has been limited by an overcommitted program. Additionally, the testing function has been burdened with problems growing out of the way the early steps in the acquisition process have been conducted.

Testing, in the system acquisition process, has not commanded the importance, stature, or priority that it must have if it is to be a primary source of information on the progress of major systems, and for decisions on:

- Continuing system design efforts
- System selection
- Starting production
- Operational deployment.

There are two main reasons why adequate testing has not been used. First, testing is expensive, difficult to stage and execute, and time-consuming. Second, advocates of major systems believe that negative test results at any stage can jeopardize a program or cause unnecessary problems and delays.

With regard to the cost, difficulty, and time required for tests, there is mounting evidence cited later in this chapter that agencies can no longer afford *not* to spend the money, take the time, and go to the trouble of performing sufficient tests. Such an investment in time and test resources may be the only way that total cost can be kept within limits of a system's operational worth to an agency.

To overcome the lack of incentive for adequate testing by system advocates, clear direction will have to be given that defines the type and expected results of various classes of testing—as is currently being attempted in DOD. Possibly the only way that such direction can be implemented is to develop a strong testing activity that will insist on doing its job.

Once testing is properly used in the acquisition process, executive branch policymakers and Congress will need to adjust to how test results should be viewed and used. Nearly all test results are part of the normal inexact engineering process of developing a new product. Most test results by themselves, at a point in time, cannot be used to determine how good or bad a system will be. However, just prior to a planned full production commitment, tests that will yield a go/no-go decision should be conducted. At this point, substantial sums

[27] Recent testimony before the Senate Armed Services Committee alleged that the Air Force using commands lacked ". . . a strong tradition for operational testing, or a strong body of expertise in operational test design, evaluation, and instrumentation . . . Often the [operational] tests reveal that expensive retrofits have to be made on initial production units, and that modifications of remaining production is necessary . . . . Seldom, however, is procurement terminated as a result of . . . . tests. Procurement decisions have already been made; production is underway; contracts and subcontracts for long-leadtime items have been let . . . In the case of many systems, the commanders and personnel of the first units implementing the 'phase-in' experience a nightmare trying to learn how to operate and maintain the new system." (Testimony of Dr. Jacob Stockfish, U.S. Congress, Senate, Committee on Armed Services, *Weapon Systems Acquisition Process Hearings*, 92d Cong., 1st sess., 1972, p. 121.)

have been spent and decisions on production and potential operational use are required. Thus, the system needs to be subjected to a tough and objective evaluation of its usefulness under expected operating conditions.

The remainder of this section will focus in more detail on:

- Illustrations of development testing problems occasioned by premature program commitments
- Discussions of operational testing practices, trends, and problems
- Specific DOD efforts to restructure testing for programs underway
- Agency organizational arrangements for operational testing
- Recommendations for further strengthening of system test and evaluation.

COMMITTING TO LARGE-SCALE PROCUREMENT CONCURRENTLY WITH DEVELOPMENT TESTING

Insufficient development testing prior to commencing major production has been typical in most acquisitions including missiles, ships, electronics, and aircraft systems. Two aircraft programs, the C–5A and the F–14, are used to illustrate the problem.

Much testing is required while a system is being developed at a contractor's plant. In aircraft programs, for example, lengthy ground tests, including static, fatigue, wind-tunnel, and propulsion tests, are made to determine whether a new airplane will be structurally and aerodynamically sound. Aircraft engineers say that at least two years of ground testing normally are required to determine what "fixes" may be needed to establish the structural integrity of a production aircraft.

The C–5A and F–14 aircraft programs demonstrated the problems that can result from lack of early developmental tests of this type. The Government has paid, and is continuing to pay, heavy "penalties" for authorizing extensive contractor production before completion of critical test phases. The overlap of production, development, and related testing is referred to as "concurrency." Illustrations of the impact of concurrency on use of test results follow.

Production of all C–5A aircraft was started and more than half of them were produced before completion of ground testing and initial R&D flight tests.[28] Operational aircraft later accepted by the Air Force had 47 major deficiencies of which 14 impaired the aircraft's capability to perform all or part of its six missions. Troublesome components included the landing gear, the wings, the pylons, and navigational and aerial delivery systems:

- In the case of the landing gear, the Air Force reported 3,300 malfunctions in a six-month period in 1971 and 83,000 maintenance man-hours expended.
- In the case of the wing, numerous failures have been experienced in ground testing causing extensive delays in completing the test. Due to the wing structural weakness, the life expectancy of the C–5A is about 7,000 flying hours as compared to a planned 30,000. Operational flying time has been restricted.[29]

The estimate to correct known C–5A deficiencies approximates $164 million which will be paid by the agency under a restructured contract. This estimate excludes problems associated with the wing and pylon, solutions to which had not been agreed upon.

When the contract was let for the F–14A, about 134 airplanes were programmed to be in production or delivered before completion of ground testing, preliminary flight testing, and inspections of the R&D aircraft.[30] The contract provides priced options for production quantities of these airplanes that must be exercised by specified dates. This drives the

[28] The test plan was prepared by the contractor and approved by the Air Force without inputs from Air Force test centers. The contractor, in effect, was the test director for his own flight tests as well as those normally made by the Air Force R&D test activity. (U.S. Air Force Systems Command, Deputy Chief of Staff for Operations, *Proposed Improvements in AFSC Test Management*, Mar. 1971, tab D, p. 1–2.)

[29] These data and those which follow on the C–5A are contained in:
U.S. Congress, House, Subcommittee of the Committee on Appropriations, *Department of Defense Appropriations for 1973*, hearings, 92d Cong., 2d sess., 1972, part 7, pp. 1177–1184.
U.S. Comptroller General, *C–5A Aircraft, Department of the Air Force*, Staff Study, Mar. 1972.
U.S. Comptroller General, Report B–163058, *The Importance of Testing and Evaluation in the Acquisition Process for Major Weapon Systems, Department of Defense*, Aug. 7, 1972, pp. 23–24.

[30] U.S. Comptroller General, Report B–168664, *Analysis of the F–14 Aircraft Program*, Aug. 17, 1970, pp. 40–48.

Navy to proceed with production before tests are completed; to wait would be to lose the price options and would necessitate the reopening of the contract.[31]

Preliminary flight tests of the F–14 reported in 1972 have disclosed 43 major problems. Sixteen of these related to safety and included engine stalling, difficulty in recovering from spins, and inadequate flight range. The Navy has reported that most of these problems can be corrected.[32] The cost of fixing those airplanes already produced and in process remains to be determined.[33]

In response to increased DOD emphasis on test and evaluation, the Air Force Systems Command examined its own practices in 1971 and asked for criticisms from all major components that test major systems. Replies were printed in an internal report that does not have official Air Force approval. The replies illustrate the problem in testing as seen from the viewpoint of field activities.[34]

Test planning and budgets

- System program office test people have insufficient experience.
- System program office test plans are late and of poor quality.
- Agency test centers do not participate in planning and establishing contract test requirements.
- System program offices do not budget enough time or money for testing.

Test operations

- Test centers do not participate sufficiently as evaluators.
- Late delivery of test articles excludes test center from meaningful independent evaluation of system.
- Production is so far committed that design redirection and modification are effectively prohibited.
- Testing must find ways for the agency to learn to "live with" the system.

OPERATIONAL TESTING TRENDS AND PROBLEMS

In recent years a number of observations and studies have been made about DOD's conduct of OT&E.

The first overall study of military operational testing was done by the President's Blue Ribbon Defense Panel. It cited fundamental problems repeated in later studies.[35]

Organization

- Testing function not independent of system sponsor or user (except Navy OT&E), a potential conflict of interest
- Test activities have insufficient stature and authority
- Military service definition of OT&E scope is narrow and interpreted differently by field personnel.

Staffing

- OT&E experience and tactically oriented test designers and evaluators in short supply.

Conduct

- Planning, execution, evaluation, reporting: marginal to inadequate
- Joint-service testing seldom performed
- Two-sided, adversarial-type testing seldom conducted
- Insufficient funds allowed for testing
- Test realism often lacking.

Utilization

- OT&E is rarely used by procuring agency for key program decisions
- Timing too late to influence design or procurement
- Test data not preserved for future weapon design, analysis, and testing.

Studies by three other groups (two instituted by DOD itself) drew upon user experience in Vietnam to emphasize the significance

[31] In testimony before the Senate Armed Services Committee in Dec. 1971, John Foster, Director DDR&E, stated that, "I believe in retrospect that the F–14 has too much concurrency." Acquisition Process Hearings, "Improved Test and Evaluation," note 27, *supra*, p. 93.

[32] DOD 1973 Appropriations, note 29, *supra*, part 7, pp. 563–565.

[33] "There has been real waste of both time and money in almost every program in which production was started before development and testing was complete. That includes almost every program." David Packard, "Improving R&D Management Through Prototyping," *Defense Management Journal*, July 1972, p. 4.

[34] AFSC DCS/Operations Study, note 28, *supra*, tab C.

[35] Blue Ribbon Defense Panel, *Report to the President and the Secretary of Defense on the Department of Defense*, appendix F, Staff Report on Operational Testing and Evaluation, July 1970, pp. 6–8.

of OT&E and demonstrate the consequences of inadequate testing.

The Institute for Defense Analyses (IDA) conducted a special study of four air-to-air missile systems because of the difficulties the missiles had encountered in combat.[36] In December 1970 the Comptroller General issued a report to Congress that dealt with the proliferation of tactical air-to-ground missiles and included the combat experience of six missiles used in Vietnam.[37] The Mitre Corporation made a study of military service operational testing of 20 weapon systems randomly selected by DOD. About half of the systems studied had been deployed in Vietnam.[38]

Because the IDA and Mitre studies were authorized by DOD itself, these two activities had great access to agency data, including user experience in Vietnam. The combined results of the systems reviewed in the three separate studies, from the viewpoint of the user, are shown in table 4.

TABLE 4. DEFENSE SYSTEM COMBAT EXPERIENCE, 1965–1970

Number defense systems reviewed		30
Less: systems covered more than once in the three studies		8
	Total	22
Number deployed to Vietnam		20
Number with which combat user had no major problems		1

Source: See notes 36, 37, and 38, *infra*. (In some cases, after additional tests, fixes, and modifications were made, the user reported more favorable results.)

Some of the 30 systems were reviewed twice since the same weapon was either studied by more than one study group or was used by more than one service. The findings of the three separate studies are similar and are reinforcing.

[36] J. S. Attinello, et al., WSEG Report 153, *Operational Test and Evaluation of Tactical Air-to-Air Missile Systems*, U.S. Weapons System Evaluation Group, July 1970.

[37] U.S. Comptroller General, Report B-160212, *Actions Needed to Reduce the Proliferation of Tactical Air-to-Ground Missiles*, Dec. 1970.

[38] D.P. Cox, et al., MTR-6084-1, *Study of Operational Testing and Evaluation Experience* (Main Study Report), Mitre Corporation, Oct. 30, 1971. The three subsidiary reports to Main Study Report are: Army OT&E Program Histories (MTR-6084-2); Navy OT&E Program Histories (MTR-6084-3); Air Force OT&E Program Histories (MTR-6084-4).

Scope of OT&E

The previously cited studies supported the introduction of a "life cycle" OT&E concept, agreeing that development time tends to slip while a deployment date tends to remain fixed, causing OT&E to be squeezed in the overall schedule. Starting OT&E with early development should alleviate this problem. One report enumerated eight fundamental purposes for conducting OT&E:

- *Affect system design*—Operational experiments could be used to determine weapon characteristics and thereby influence designs.
- *Affect missions for systems*—When troops use a system in a well simulated operational environment, missions tend to be defined better and new missions may be developed.
- *Aid in resolving controversy*—Differences over systems may be political, technical, or operational and may involve the relative merits of competing systems.
- *Minimize operational surprises*—Get data on reliability, missions, maintenance, tactics, constraints, techniques, and procedures before the systems are deployed so that combat commanders will know what to expect from new systems.
- *Develop and improve combat doctrine, tactics, and constraints.*
- *Reveal desirable system modifications*—Find remedies to system deficiencies from an operational point of view.
- *Affect subsequent procurement*—OT&E yields the first credible evaluation of how useful new systems will be in combat including comparison with existing systems.
- *Affect tactical organization*—OT&E results can help determine crew size, efficient deployment, and the nature of organizational changes to exploit the new system.[39]

Early testing to assess the validity of a system feature or requirement does not require the complete development of a contemplated system. For purposes of field testing, an exist-

[39] Mitre Main Study Report, note 38, *supra*, pp. 19–20.

ing system may be modified to simulate certain features of a contemplated new system or subsystem; or experimental models can be built with most of the critical features planned for new, fully developed systems. A proposed new guidance system, for example, can be tested with an existing guided missile. The simulated system can be tested against actual targets in a variety of terrains and related combat conditions.[40]

Little testing of this kind is being done currently and is not required by DOD policy. Recent testimony at Senate Armed Services hearings on major systems emphasizes:

> Military personnel need a chance to test a development prototype in operational tests, and on the basis of this experience they will be in a position to write realistic requirements for the procurement process.[41]

Planning, Execution, Reporting of Test Results

Each of the three cited studies found that planning, execution, and reporting of military OT&E can be much more effective. Some of their findings were that:

- Factors enhancing the value of tests: experienced test personnel to devise plans and objectives; test teams composed of operationally oriented military personnel and professional civilian analysts; and typical operational units to carry out the tests.
- In general, specific criteria that should have been used to evaluate performance were omitted from test reports. Noticeably lacking were specific operational requirements that the test systems were to meet.
- Too much OT&E time was spent verifying technical performance and uncovering dissatisfactions that should have been discovered during earlier development testing.
- Reported satisfactory system capability often was based on limited test results or on testing that addressed a narrow test objective under limited test-range conditions.
- No mechanism existed to disseminate and interchange expertise and data among OT&E organizations or to preserve such data.

Timing of Testing

Despite regulations to the contrary,[42] major production was authorized before the operational usefulness of a system had been determined. Findings on 20 cases are shown in table 5.

TABLE 5. TIMING OF OT&E

OT&E conducted during system development	3
OT&E conducted after major system production underway	9
OT&E conducted after system in hands of operational units	8
Total	20

Source: Mitre Main Study Report, note 38, *supra*.

The R&D program manager needs operational test data as soon as it can be made available. He has few options later when he is confronted with operational problems that require expensive R&D solutions. During the design stage, the OT&E user-oriented test teams could assess the value of demonstrated operational characteristics; in the prototype stage, OT&E can help minimize the need for costly changes in production articles. In a number of cases examined, it was impractical, because of the cost and time involved, to correct deficiencies discovered when the system was in production.

The Blue Ribbon Panel said:

> The question of timeliness is extremely important. For this reason it is essential to dispel the widely-held belief that useful OT&E must await the completed product of R&D . . . It is important to perform OT&E on operationally configured production systems. If the OT&E process only commences at that point it misses most of the opportunity to

[40] According to a Feb. 1972 survey report by representatives of the Army Materiel and Combat Developments Commands, larger NATO military organizations conduct early field experiments to assess combat effectiveness and technical feasibility of new system requirements.

[41] Testimony by Dr. Wm. B. McLean, Acquisition Process Hearings, note 27, *supra*, p. 228.

[42] In those areas where various testing processes had been established, there were so many approved deviations, substitutions, waivers, and examples of special circumstances that we concluded that there was a need for better understanding of the basic theory and application of testing in DOD. See GAO Acquisition Report, 1972, note 9, *supra*, p. 58.

influence that product on behalf of operational forces—the ultimate users.[43]

The early involvement of operational testing that is desirable at key points in the system acquisition process is shown in figure 3 at the beginning of this section.

The Test Hiatus

It has been often contended that thorough testing, prior to production, invariably means a program delay that will increase costs. For example, an agency or a congressional committee might challenge a production go-ahead decision and related funding on the basis that a new system had not been tested sufficiently. A program advocate might respond with an analysis of the increased cost of delaying production in order to conduct testing. He is correct; there will be substantial added cost but much of it is *not* attributable to performing adequate test and evaluation.

The problem usually can be traced to how development and production programs have been structured in the past. An unrealistically short schedule usually is demanded by an agency when it holds an industry competition for the development of a new system. In order to win the development program, the contractor structures his proposal to meet this unrealistic schedule. After the winning contractor receives his contract, he has to assign a large number of people exclusively to the program in order to meet the schedule, and arrange to have subcontractors in similar positions, all waiting to go to the next step. Any delay under these circumstances is naturally very expensive.

If the program had been phased properly in the beginning, with a smaller number of personnel and with an allowance for testing, neither the agency nor the contractor would be faced with the high cost of a "test hiatus."

The use of smaller development teams could solve the problem if Government specifications were simplified and if extensive documentation requirements were deferred until final design was better known.[44] This approach permits assignment of only those key technical personnel needed for direct work on the initial development. Personnel so phased into the development would later participate in the test and evaluation of its results. Additional work could start immediately on any developmental or design problems revealed by the testing process.

As components and subsystems prove themselves during the testing phase, detailed designing for production can begin. Production drawings, tool design, process planning, and the like do not involve the high, irrevocable funding risks that accompany production equipment and fabrication of hard tools.

Finally, if required by program urgency, some judicious concurrency can be authorized. Work can begin and orders can be placed for long-leadtime production items of lower risk, and the contractor can proceed with limited production. In any event, a major investment can be deferred until there is a sound basis to proceed with production.[45]

Realism of Testing

As for the "realism" of operational tests, table 6 shows that approximately half of the 20 systems previously cited were not tested under combat-like conditions.

TABLE 6. REALISM OF OT&E

Characteristics of realism	*No. of 20 systems tested which included characteristics of realism*
Operated by typical operational units	8
Supported by typical operational units	10
Realistic force composition	14
Combat stress placed on forces	7
Combat simulation of troop environment	6
Realistic combat tactics	7
Combat duration of tests	8
Realistic physical environments	9
Target system approximates combat reality	8
Realistic actions by opposed forces	9

Source: Mitre Main Study Report, note 38, *supra*.

[43] Blue Ribbon Staff Report on OT&E, note 35, *supra*, p. 12.

[44] See: U.S. Comptroller General, Report B-39995, *Evaluations of Two Proposed Methods of Enhancing Weapon System Procurement*, July 14, 1969, p. 25–28.

CG Missile Proliferation Study, note 37, *supra*, pp. 65–67.

U.S. Congress, Senate, Committee on Armed Services, Hearings, testimony of Thomas V. Jones, President, Northrop Corporation and Clarence L. Johnson, Senior Vice President, Lockheed Aircraft Corporation, 92d Cong., 2d sess., May 12, 1972. (mimeo)

[45] The frequent complaint about the delay caused by testing was recently countered by former Deputy Secretary of Defense Packard: "I found hardly a program that was not delayed anyway. I hardly found a program that would not have been in better shape if it had been planned and managed from the beginning to complete the development and testing before getting too far along in production. In the past, delays have been incurred and hundreds of millions of dollars have been spent unnecessarily." (Packard Prototyping Article, note 33, *supra*, p. 5.)

About half of the operational testing was done at agency R&D test centers. Other services participated in 30 percent of the programs and their "devil's advocate" role increased the value of the tests. Mitre concluded from the sampling that the degree of realism achieved in operational tests and evaluation was low and varied according to the service performing them:

Programs	*Degree of Realism*
Army	55 percent
Navy	46 percent
Air Force	31 percent

Some of the individual findings and lessons learned about the degree of OT&E realism are:

Valid Test Setting

• OT&E that demonstrates what is likely to happen when a weapon is put in the hands of typical troops in combat should be required before deployment. A good operational test environment contains variables in combat procedures, habits, practices, tactics, and a range of physical environments.

• A realistic OT&E is more like a tactical exercise than a test. For example, one missile test involved a brigade size operation (with an opposing military service participant), realistic tactical maneuvers in accordance with combat-like scenarios, aggressors vs. friendly forces, realistic air operations by high-performance tactical aircraft, and operating command and control centers.

Invalid Test Setting

• Realistic OT&E of small surface-to-air missiles was seriously limited by targets that were too slow, unable to maneuver, had unrealistic radar reflections, and were unable to fly combat profiles.

• One naval surface-to-air missile was tested under clear skies in the absence of other aircraft and when seas were calm. Its success depended on the gunner's ability to recognize friendly aircraft visually. Identification of friend or foe was not part of the test, however, and no surprise targets were used to measure crew reaction. Also drones and aircraft flew straight, unswerving courses that were easy to track.

Two-Sided and Joint-Service Testing

Often weapon systems are designed for missions that need the collaboration of two or more services, such as in close air support for which the Air Force develops aircraft and air-to-ground ordnance to support Army ground troops. Weapons to be used in collaborative missions call for "joint-service testing." (Realistic testing is done safely with gun cameras, dummy warheads, drones, and other devices.) All weapons tested, including those for joint-service missions, are better understood after confronting opposing equipment, countermeasures, realistic terrain, and adversarial tactics—"two-sided testing."

Most operational testing has been done by the individual services without using an opposing force. Yet, in the few instances when OT&E was done jointly with another service, the test value increased considerably.[46]

The Deputy Secretary of Defense sought to change the opposition to joint-service and two-sided testing in a 1971 memorandum to principal department officials that advocated these types of tests.[47] A recent major inter-service test has been reported on the Air Force's Maverick tactical air-to-ground missile. DOD plans to joint-test several other systems during 1973 and 1974.[48]

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[46] ". . . in most actual combat environments, the United States must conduct combined operations. The interactions among services become extremely important during combat, and critical military missions transcend service boundaries and responsibilities (for example close air support, reconnaissance, and air supply). Because of the lack of joint OT&E, it is not only very difficult to detect certain kinds of deficiencies and to predict combat capability in advance, but it is also difficult to make decisions relating to overall force composition." Blue Ribbon Staff Report on OT&E, note 35, *supra*, pp. 38–39.

[47] Memorandum from the Office of the Deputy Secretary of Defense to the Secretaries of the Army, Navy, and Air Force; Chairman, Joint Chiefs of Staff; and Director of Defense Research and Engineering, subject: "Conduct of Operational Test and Evaluation," Feb. 11, 1971.

[48] Acquisition Process Hearings, note 27, *supra*, p. 71.

Test Facilities

DOD operational test facilities are marginal in terms of realism and there is serious concern if the deficiency will be overcome by future requirements for test ranges and facilities. The IDA report on operational testing of air-to-air missiles, for example, discussed the inhibitions of test-range space, instrumentation, manuvering targets, telemetry provisions, and safety requirements.

A DOD joint review group concurred that facilities available to the services for OT&E generally should be upgraded. Instrumented test areas should be expanded and upgraded for vital measurements of system performance; professional testing expertise within the using commands and additional data processing facilities are needed; and to provide realism in the conduct of testing, more room is needed in terms of use of air, land, and water space and radio frequencies.[49]

Organization of Operational Test and Evaluation Activity

Over the years, the military services have been organized to carry out their OT&E activity as follows: [50]

- An independent organization reporting to the service chief (Navy)
- An organization subordinate to the developer (Army)
- An organization subordinate to the user (Air Force).

Thus, there are basic differences among the military services over OT&E organizational arrangements. Preceding discussions indicate that there are two principal organizational needs for a sound OT&E operation:

Sufficient stature, authority, resources. The military service itself develops and produces few major systems; primarily it acquires sufficient information (such as test results) to manage the program and to support important decisions on:

- Continuing private sector system design efforts
- The choice of a system the agency will procure from the private sector
- When the chosen system should enter final development, production, and deployment phases.

The organization gathering and assessing this information should have considerable stature and objectivity, adequate resources, and experienced, trained personnel.

Independence and Impartiality. To be independent and impartial, OT&E components should be distinctly separate from the organizations that sponsor or will use a major system.

The developmental activity should not be the evaluator of its own product. Program momentum and advocacy is pervasive in major system procurements and a new defense program often acquires powerful organizational support in the service or at department levels. It is very difficult for those responsible for developing a system to remain objective about it. Therefore, the test data, evaluation, and reporting must be credible and come from a separate source.

There are several reasons why the user should not have primary responsibility for operational testing. The user is directly involved in the evolution of and requirement for the system and usually applies pressure to have the system deployed as soon as possible. The user has many overriding demands on its own resources that are concerned with its *primary missions*. Operational testing should receive emphasis and become a professional career activity in the agency. A high level of training is required and the personnel assigned should have scientific, operational, and analytical skills. During the past decade, only the Air Force has assigned operational testing to the user. The studies cited earlier indicate that operational testing in the Air Force has received the least emphasis and has not been effective.

The organizational arrangement that best

[49] U.S. Department of Defense, Test and Evaluation Study Group, *DOD Test and Evaluation Base Review*, U.S. Director of Defense Research and Engineering, Aug. 1971, pp. 96–111.

[50] Concerning organization; the Blue Ribbon Defense Panel Report recommended an Assistant Secretary of Defense be established with responsibility for T&E policy and a separate defense test agency be established under the new Assistant Secretary. This agency would be responsible for design or review of test programs, performing or monitoring tests, and continuous evaluation of the entire T&E effort. (Blue Ribbon Defense Panel, *Report to the President and the Secretary of Defense on the Department of Defense, Summary Report*, July 1, 1970, p. 91.)

satisfies the two needs described above would be the one similar to the Navy: a separate activity reporting to a high level. The Army recently established a separate activity to perform OT&E and is scheduled to be fully operational in April 1973.

Operational Testing of Future Systems

To assess present trends in OT&E, the Commission analyzed seven Army, nine Navy, and seven Air Force programs now in various stages of development and production. They account for a large number of defense systems to be available to the military service operating forces during the 1970's, 1980's, and 1990's. The review focused on the timing and nature of the operational testing and the current status of the programs. Table 7 summarizes the findings.

TABLE 7. OPERATIONAL TESTING OF DEFENSE SYSTEMS CURRENTLY IN DEVELOPMENT OR PRODUCTION

Number reviewed	23
Number allowing substantially more time than in the 1960's for operational testing	12
Number where testing continues to be late, crowded, or insufficient	11

Source: Appendix A.

"Crowded or insufficient testing" as used in the table means that extremely limited operational tests are scheduled over a short time span before the agency head must make a production decision. "Late testing" as used in the table means that OT&E follows, rather than precedes, the production decision. Most of the questionable programs were structured before DOD implemented its recent test policies. Although newer programs are allowing for more testing than those of the 1960's, inevitable delays in development will eventually compress the testing time unless operational capability dates for the systems remain flexible.

Congress has recently acted to secure more control over new defense systems by adding Section 506 to the 1972 Authorization Act. This section provides for the submission of an annual report that, in part, calls for OT&E results on systems for which procurement funds are being requested.[51]

Conclusions and Recommendations

- There were serious weaknesses in the test and evaluation practices followed by DOD in the 1960's and early 1970's.

  In many procurement decisions, military services relied extensively on contractor testing and monitoring while their own development test activities were relegated to limited support-type roles.

  Major systems of unproven technical performance and operational worth were committed to large-scale production while critical development testing was underway and before operational test and evaluation had been performed.

  The kind of test and evaluation that examines a defense system from an operational point of view was not sufficiently emphasized in making decisions to enter full production. Seldom present in the tests were combat-like conditions, a range of skills of intended users, or a simulation of enemy responses, including adversarial tactics, camouflage, countermeasures, and other variables.

  Military scientists, engineers, and analysts were handicapped in evaluating desired weapon capabilities by the lack of accumulated operational test data and measurements.

  Many defense systems deployed to the field and to combat did not perform as required or were unreliable in operation.

  Improvements in DOD test and evaluation practices, personnel, and organization during the 1960's did not keep pace with the needs of the more demanding and complex systems being developed.

- In the absence of a vigorous OT&E function, there is no activity in agency components with the substantive data-gathering capacity needed to objectively evaluate the progress of major defense systems and their readiness for production and deployment.

[51] Public Law 92-156, 85 Stat. 423, Nov. 17, 1971.

• In the 1970's DOD has taken strong actions to reverse these trends by:

Establishing a DOD T&E office to set policy and to monitor for the Secretary test operations of the military services

Emphasizing earlier development and operational testing in new programs and readjusting some of the testing in ongoing programs

Reducing the overlap between development and production

Focusing attention on test results at key acquisition decision points.

• Some of the defense system programs scheduled for development and production during the early and mid-1970's are not organized to provide for a sound OT&E before major procurement funds are committed.

• A DOD-wide definition of the scope of OT&E is lacking; this complicates monitoring of service test plans and operations.

Recommendation 9. Withhold agency head approval and congressional commitments for full production and use of new systems until the need has been reconfirmed and the system performance has been tested and evaluated in an environment that closely approximates the expected operational conditions.

(a) Establish in each agency component an operational test and evaluation activity separate from the developer and user organizations.

(b) Continue efforts to strengthen test and evaluation capabilities in the military services with emphasis on:

(1) Tactically oriented test designers

(2) Test personnel with operational and scientific background

(3) Tactical and environmental realism

(4) Setting critical test objectives, evaluation, and reporting.

(c) Establish an agencywide definition of the scope of operational test and evaluation to include:

(1) Assessment of critical performance characteristics of an emerging system to determine usefulness to ultimate users

(2) Joint testing of systems whose missions cross service lines

(3) Two-sided adversary-type testing when needed to provide operational realism

(4) Operational test and evaluation during the system life cycle as changes occur in need assessment, mission goals, and as a result of technical modifications to the system.

CONTRACTING

Selected contracting topics concerned with final development and production stages of major system acquisition are examined in this section.

Background

In the 1960's, DOD shifted from cost-type to higher risk, fixed-price-type contracts with multiple incentive clauses in an attempt to eliminate cost overrun problems in major systems. Ultimately, this transfer of risk led to "total package procurement" that combined development and production into a single contract. Such an arrangement called for obtaining contractual commitments on performance, schedule, and price of production systems before development began.

The C–5A, SRAM, Cheyenne helicopter, and F–14 programs are examples of total package procurements. The contracts have since been revised or terminated; a remedy for the F–14 contract is still pending. Current DOD policy has reverted back to the use of a cost-type arrangement if the contract is to cover substantial development work.[52]

Problem Discussion

Historically, major system acquisition programs have been tailored to fit currently popular procurement methods. As contract types were tried and their shortcomings discovered, new contract forms were devised, such as

[52] DOD Directive 5000.1, note 25, *supra*, p. 5.

the total package procurement and multiple-incentive contracts of the 1960's, and tried on new programs. Performance and cost problems did not surface at the top agency and congressional levels until they became acute many years later. Then much of the criticism focused on the contractual arrangement, negotiated price, and contract administration.

Problems associated with contracting, including "cost growth," have been the most painful symptoms of the basic inadequacies in the structure of system acquisition programs. Contracting methods and procedures have been singled out as a remedy for past ills. This worsened basic problems by increasing the number of contracting regulations that are applied to important programs, whether appropriate or not.

Problems encountered during contract performance are rooted in actions or inactions related to the early phases of the acquisition process. These problems formed a fertile field for cost growth, claims, schedule delays, and performance disappointments. The intended cumulative effect of recommendations made in this report is to acquire enough information to choose a system suitable to meeting the agency's need and goals, to change the major system contracting environment from one of competitive promises to competitive demonstration, and to minimize the difficulties in present-day contract administration.

Competing system-level technical approaches and a test demonstration phase should provide realistic Government specifications for final development and a basis for simplified contractual arrangements. With the understanding that contracting for final development and production can only be as effective as the acquisition process that precedes it and that it will be influenced by the recommendations made in earlier chapters, this section of the chapter focuses on the following subjects of continuing interest in major system contracting:[53]

- Use of priced production options
- Special clauses relating to:
  Limitation of Government's obligation
  Total system performance responsibility
  Contract changes
- Use of detailed regulations.

USE OF PRICED PRODUCTION OPTIONS

In a reaction to contracting problems of the 1960's, current DOD policy[54] precludes the use of total package procurement and the use of priced production options in development contracts. Complete elimination of production options means that DOD components should not contract in advance for limited production even if remaining development work is relatively straightforward.

Priced production options are sometimes desirable to encourage the contractor to design for economical production and to avoid a costly break in production preparations. Use of sustained competition in the acquisition process has been recommended earlier. This will provide hardware test information on critical new system features before final development and production decisions are made. With reduced or "manageable" uncertainties and better information, program officials may find it advantageous to include priced production options in a final development contract. The options may be exercised if justified by a final development evaluation, or deferred until satisfactory test evidence is available, or waived entirely.

LIMITATION OF GOVERNMENT'S OBLIGATION (LOGO)

Fixed-price-type contracts limit the Government's monetary obligation. For example, the maximum limitation of fixed-price incentive contracts is the ceiling price. Currently included in some long-term, cost-reimbursement contracts for major systems is a relatively new "Limitation of Government's Obligation" (LOGO) clause.[55] The clause is used, for example, in the Air Force F–15, B–1, and AWACS contracts to limit the Government's monetary obligations in cost-type contracts.

[53] Subjects common to major systems as well as other types of procurement, such as cost principles, truth in negotiations, etc., are covered in Parts A and J.

[54] DOD Directive 5000.1, note 25, *supra*, p. 5.

[55] Air Force Systems Command (AFSC), ASPR Supplement 7–302.2(a), Oct. 14, 1970.

The LOGO clause affects the entire spectrum of contract obligations. It establishes yearly funding limits, even though the contract is of the cost-reimbursement type. The Government is not required to reimburse the contractor in any year in an amount greater than that stipulated in the contract for that year. The contractor does not have a collateral right to stop or slow down work if he exhausts a given year's funds.

The contractor is funded until his expenditures coincide with the amount in the LOGO clause for the yearly increment. At that point, if his actual expenditures are ahead of planned expenditures, he must use his own funds until the Government makes the following year's increment available.

In some programs, the yearly funding limits are fixed and are not subject to change for the first three fiscal years. After three years, the yearly funding limits can be changed, but the contractor must petition the Government 17 months prior to the start of the fiscal year period in order to accommodate the agency's budgetary cycle. Under this arrangement, a contractor must be able to make predictions and to substantiate them well in advance. The LOGO mechanism potentially provides an agency with a degree of budgetary funding integrity and stability usually not characteristic of cost-type contracts.

The clause is deceptively simple but requires great managerial skill to apply. It requires that detailed program financial planning be done far in advance of the work to be accomplished. The clause has greater application to a long-term commitment made to one system when the uncertainties of cost, performance, and schedule dictate use of a cost-type contract. The clause would not be appropriate, for example, to competitive system contracts that limit development work to prototype demonstration and specify the amount that each contractor can recover from the demonstration effort.

TOTAL SYSTEM PERFORMANCE RESPONSIBILITY CLAUSES

During the development and production of a major system, a prime contractor may not be permitted to select, make, or procure all the elements of a system. For example, the Government may decide to furnish the radars and, in some cases, other subsystems to be installed as Government-furnished equipment (GFE). In these circumstances the Government still places the responsibility for overall system performance and correction of deficiencies on the contractor through a total system performance responsibility (TSPR) clause.

In the case of the Air Force F–15 program, the clause states that before the Government accepts the engine, the system contractor will concur in the engine specification and test program and then concur that the engine submitted meets the specification. If appropriate, the system contractor will enter into a written agreement with the engine manufacturer on any corrective action needed. Similar provisions are made for other GFE.[56]

The agreement between the two contractors is known as an "associate contractor agreement." It covers coordination of engineering change proposals, approval of specifications, financial responsibility for correction of deficiencies, and responsibility for changes. Administrative procedures are specified and rules covering appeals and arbitration are included. Government TSPR clauses must be accompanied by associate contractor agreements.

The central feature of the Navy's TSPR clause is the contractor's responsibility for "feasibility of performance." The contractor is obligated to review and study the proposed specifications for the major weapon system so that he can attest to their feasibility. He will be responsible for any conflict between his proposed design and the performance specifications.[57]

The contractual assumption of total system performance responsibility by the contractor, including the assumption of risk for subsystems that he did not design, develop, fabricate, or procure has not been tested in the courts. Features that may render the TSPR clause

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[56] Brig. Gen. B. N. Bellis, presentation to the Aviation/Space Writers Association, Washington, D.C., Feb. 6, 1970, USAF News Release, Feb. 6, 1970.

[57] Melvin Rishe, "The Acquisition of Major Systems Procedures and Problems," *National Contract Management Journal*, spring 1972, pp. 93–94.

provisions ineffective are acts of commission or omission made by the Government.

A basic tenet of this report is that a contractor should have the latitude to make product decisions in preliminary design phases and be held accountable for the results of those decisions in competition with others. In such cases, TSPR clauses would not be necessary.

Total system performance responsibility clauses are, therefore, more relevant to an unproven system chosen very early in the acquisition process. In these situations the system to be developed is usually defined from multiple design contributions received from various segments of industry and Government. Responsibility for defining the original system features is diffused. It is preferable in these situations that the Government recognize its role and assume primary responsibility. Such an assumption of responsibility necessitates a strong Government program office with a high degree of technical competence.

SPECIAL CLAUSES FOR CONTRACT CHANGES

The management and control of contract changes is a vital part of major system acquisition programs. Many contract changes result from engineering change proposals (ECPs) that are initiated by the contractor or the Government. The changes may be initiated to incorporate design improvements or correct deficiencies identified during system development or production.

The issues discussed below are common to all procurement, but are discussed here because of the amount of cost growth associated with ECPs and the vastness of claims arising from constructive changes in major system acquisitions.

Program offices process proposed engineering changes through a so-called configuration control board to assess and account for design changes. This board, which generally reports to the program manager, evaluates the technical content, cost, and schedule effects of the proposed changes and forwards approved ECPs to the contracting officer for contractual action.

There are many kinds of ECPs that the Government must be able to process within the contractual framework.[58] The most common is an ECP proposed to improve or otherwise change system performance with an increase in contract cost. In this case, the Government must determine if the change in performance is worth the increased price.

The standard Government clause authorizes a contracting officer to issue changes unilaterally in specifications, schedule, place of delivery, or method of shipment that the contractor must use.[59] To assure that a change is priced immediately and not after its completion, the changes clause usually requires the contractor to assert his claim for "equitable adjustment" within 30 days from receipt of the change notice.

In order to control unexpectedly large budgetary demands arising from ECPs, DOD components recently began modifying the changes clause to include a "not-to-exceed" provision.[60] It requires the contractor to accompany each ECP with a not-to-exceed cost for equitable adjustment. The ECP is evaluated on the basis of this maximum amount and, if accepted by the agency, the equitable adjustment may not exceed the amount.

For some ECPs, the ceiling price submitted with a proposed change must be highly speculative. The ceiling control feature has been adopted based on experience under contracts let for undemonstrated systems. The clause appears to be a patchwork solution to a more basic problem of poor initial definition of a system that requires numerous later changes.

Constructive Changes

In the 1960's the shift in contracting policy from cost-reimbursement to fixed-price-type contracts for final development and initial production gave rise to claims based on "constructive" changes. Unlike cost-type contracts, fixed-price contracts could not accommodate many changes within existing contract funding.

A constructive change order is defined as any action taken by a Government representative that is not a formal change order but has

[58] One kind, a "no cost" change, may signal a relaxation of specifications.

[59] ASPR 7-103.2, and FPR 1-7.101-2.

[60] Air Force ASPR Supplement, 7-103.2.

the effect of requiring the contractor to perform work differently from that prescribed by the original terms of the contract. Normally, such direction would constitute breach of contract. However, a theory of "constructive changes" that accommodates these situations has evolved under the standard changes clause included in most Government contracts. When it is concluded that a change order should have been issued by the agency under the changes clause, the case is treated as if this had been done and the Government is required to make an appropriate equitable adjustment.

It has been alleged that technical problems and cost overruns are sometimes hidden under the guise of "constructive changes." Navy shipbuilding programs suffered from a rash of claims, many of which were for constructive changes. A recent GAO review found that ship claims settlements were averaging 37 percent of the original contract prices and that some current claims for price increases amounted to more than half of the original contract price.[61] As of February 1972, there were $824.2 million of unsettled claims involving Navy shipbuilding programs.

Problems resulting from the application of total package procurement methods to shipbuilding were similar to those encountered in aircraft programs. Such problems were accentuated by formally advertised procurements for ships that did not include firm, proven specifications. Often there were difficulties in ship system integration due to large amounts of GFE, much of which was under concurrent development. These situations continue to provide a fertile environment for claims.

The Navy has taken a series of actions to reduce some of the causes of these claims, including training courses for specification writers and inspectors, with an emphasis on avoidance of constructive changes. Its new shipbuilding contracts call for competitive development of designs for the lead ship of a particular class such as patrol frigates, with accent on producibility.

The Navy has also adopted a controversial anticlaims clause.[62] The clause requires the contractor to advise the contracting officer of any communication from the Government that he considers to be a constructive change order within ten days of the receipt of the communication. The contractor also must provide information on the direct and foreseeable consequential effects of the order, and refrain from any action until he has been advised in writing by the contracting officer on its disposition. To insure that contractors immediately notify the Navy of these circumstances, the clause states that the contractor complies at his peril with orders, directives, interpretations, or determinations from someone other than the contracting officer.

A clause similar to the Navy's has been proposed for inclusion in ASPR.[63] An additional feature is aimed at the curtailment of constructive changes. A specific delegation is required from the contracting officer to anyone who is to be his "authorized representative." The letter of delegation is to spell out the specific areas of authority and the effective period of the delegation.

USE OF DETAILED PROCUREMENT REGULATIONS

The procurement of major systems is governed by the Armed Services Procurement Regulations (ASPR) in DOD, by the NASA Procurement Regulation (NASA PR), or by the Federal Procurement Regulations (FPR) in most civilian agencies. The NASA PR and FPR are patterned largely after ASPR.[64]

When first published, ASPR contained less than 100 pages. It was intended to be a policy document; service-level regulations provided procedural detail. Over the years, ASPR has grown to about 3,000 pages and service regulations still exist.

There is widespread dissatisfaction with the size and detail of the procurement regulations. Common complaints are the frequency of change, the lack of flexibility permitted in applying policies and procedures, and the practical impossibility of being able to understand and intelligently apply all that is included in it. Many of the policies and clauses in the regulations were developed in response to special

[61] U.S. Comptroller General, Report No. B-133170, *Causes of Shipbuilders' Claims for Price Increases*, Feb. 28, 1972, p. 5.

[62] U.S. Department of the Navy, *Navy Procurement Circular #15*, Mar. 6, 1970; and *Navy Procurement Circular #18*, Oct. 27, 1970.

[63] U.S. Department of Defense, ASPR Committee Case Listing, May 22, 1972, ASPR Case 70-103.

[64] The regulatory framework is covered in detail in Part A. Chapter 4.

problems with particular contractors or for unique kinds of procurement.

The acquisition of major systems is different than the purchase of more conventional items and commercial products. The deviation and waiver routes required in order to get authority to use nonstandard clauses and to follow procurement methods appropriate to major systems takes time and unnecessarily diverts personnel from their main task.

The major system acquisition process is characterized by the uniqueness of development tasks, different weightings of objectives, peculiar needs, and pervasive uncertainties. Just as innovation is required to solve the technical problems in designing and developing the system, the exercise of sound and seasoned judgment is necessary to conclude a business arrangement that links the Government to a major system contractor and takes into account the uncertainties and risks that will burden the program.

The personnel assigned to major system procurement should be the best available to the procuring organization. They should not need a detailed formula to substitute for judgment. Excessively detailed guidance, and required use of ineffective contract provisions can impede major system acquisitions. Adequate authority to adapt, to modify, to innovate, and to be responsible for actions taken is needed.

Conclusions and Recommendations

- When system acquisition uncertainties are reduced to an acceptable level in early development, the use of priced production options in contracting for final development may be advantageous and should be permitted.
- Special contract clauses involving limits of Government obligation, contractor total system responsibility, and contract changes represent efforts to fix problems rooted in early acquisition phases. Such clauses do not cure these problems; rather they increase the complexities of contracting and administration and some tend to generate contract claims and disputes.
- Procurement regulations have developed into voluminous detailed documents that do not accommodate the flexibility and experienced judgment needed to accomplish major system program objectives.

Recommendation 10. Use contracting as an important tool of system acquisition, not as a substitute for management of acquisition programs. In so doing:

(a) Set policy guidelines within which experienced personnel may exercise judgment in selectively applying detailed contracting regulations.

(b) Develop simplified contractual arrangements and clauses for use in awarding final development and production contracts for demonstrated systems tested under competitive conditions.

(c) Allow contracting officials to use priced production options if critical test milestones have reduced risk to the point that the remaining development work is relatively straightforward.

MANAGEMENT OF PROGRAMS

Because of large resource requirements, high technological content, and importance to an agency mission, system acquisition programs have demanded special top-level management attention. Such programs are usually managed within an agency by an office especially set up for that purpose.

Background

System program management[65] oversees the organized effort undertaken to meet a specific agency need, including the evolution of a system, its development, and production. Some of the principal functions it oversees and coordinates are program funding, system engineering and integration, developmental test and evaluation, and contracting.

The program management concept stems di-

[65] "System program management," as used in this report, covers the various designations used by different departments and agencies, such as "program" or "project" management. The title "program manager" is synonymous with "project manager" or "program director."

rectly from the centralized coordination required in a system approach. The concept involves a central office with overall responsibility and authority for a major system, headed by a program manager. The concept calls for centralized planning and coordination of all actions by participating organizations within the agency.

With the advent of the program office and the evolution of the program management concept in the 1950's, the typical role of a Government contracting officer has changed. In most other types of Federal procurement, the contracting officer, for all practical purposes, is the "program manager." Under a program management concept, however, he is one of many functional specialists working with the program manager. In some cases, the program manager is vested with a contracting officer's authority.

DOD has taken positive action in recent years to upgrade the stature, career development, and assignment of program managers. Program continuity is being encouraged by retaining the manager on the program as long as possible.

Problem Discussion

A system acquisition is a lengthy, complicated process that usually proceeds through development and production with all resources directed to one yet unproven system. The program manager works in a sole-source environment and, if an agency's need for the improved capability continues or becomes urgent, he must extricate the one system from the development process for operational use.

Absence of substantive competition in the system acquisition process has created expensive bureaucratic controls in Government and industry that check and balance the process. These controls have taken the form of increased staffs (management layering), information systems, and voluminous procurement rules and reporting requirements. Overlying the complexities and frustrations of program management are these continuing problems:

- Responsibility and authority for major system policymaking and monitoring are diffused at the agency head level and, below that level, scattered among many offices down through component levels.
- Acquisition policies and the procurement tools to carry them out are established separately by specialists. These functional specialists do not closely interact when new programs are being structured; thus technical and business management considerations are applied in separate phases, not on an integrated basis.
- Program managers are assigned after the system itself is conceived and thus do not participate in some important decisions that eventually influence program execution and success, which are their responsibility.
- Program managers cannot exercise effectively the authority and responsibility delegated to them due to excessive management layering and numbers of reviews, coordination points, and staffs that must be kept informed or from whom approvals must be obtained.

DIFFUSED AUTHORITY AND RESPONSIBILITY

The R&D and procurement policy staff functions at agency and component top levels each have their own specialists and have seldom interrelated well in major system acquisition. Each has authority and responsibility to develop policies that influence the conduct of acquisition programs. The split in authority and responsibility between the two offices makes it difficult to integrate technical and business management planning, correlate changes in policies, monitor policies, or determine responsibility for policies and their ultimate results as explained below.

The major system decisionmaking process in DOD provides for a Defense Systems Acquisition Review Council (DSARC) to be convened at critical decision points.[66] Table 8 shows the decision points reserved for the agency head, and those delegated to the operating military components.

When a DOD component has determined a need for a new program, it will consider alternative system solutions until it has chosen

[66] DOD Directive 5000.1, note 25, *supra*.

TABLE 8. DOD MAJOR SYSTEM ACQUISITION AGENCY HEAD AND COMPONENT DECISION POINTS

	DDR&E monitors	*DDR&E chairs DSARC I*	*DDR&E chairs DSARC II*	*Asst. Sec'y. I&L chairs DSARC III*
	2	4	6	8
Office Secretary of Defense	Allocates funds	Approves system demonstration	Approves final development	Approves production
	1	3	5	7
Military component(s)	Solicits proposals and studies; conducts in-house work	Selects, defines system for demonstration, submits DCP [a]	Submits demonstration results	Requests production release

[a] Development Concept Paper; program manager normally assigned at this point.
Source: Commission Studies Program.

a particular system. Then a development concept paper (DCP) covering a new system is prepared for submittal at DSARC I. This paper is reviewed by several different staffs at the Office of the Secretary of Defense level but primary review jurisdiction is with the Director of Defense Research and Engineering (DDR&E).

Following approval, a program manager is normally assigned and system development starts. When the DOD component is confident that the program is ready for final development, the development concept paper is updated and the program is again submitted for review (DSARC II). When final development is completed, the same process (DSARC III) is used to decide on the production and deployment phase. In this third DSARC decision, primary jurisdiction for review shifts to the Assistant Secretary of Defense (Installations and Logistics) who is responsible for the procurement, production, and logistic functions of system acquisition. Thus, the Director of Defense Research and Engineering is chairman of DSARCs I and II and the Assistant Secretary of Defense (I&L) is chairman of DSARC III.[67]

As part of its responsibility for the early phases of major system acquisition programs, DDR&E develops overall acquisition policies as expressed in DOD directives. The Assistant Secretary (I&L) also issues policy in the form of the Armed Services Procurement Regulation (ASPR). These regulations set policy for all procurements as well as for all phases of major system contracting. Policies governing major system acquisition are therefore divided between ASPR and DOD directives.

The development concept paper provides planning for technical elements and program needs and identifies possible solutions to foreseeable problems in development and testing. This early technical planning is not complemented by involvement and interaction with procurement, production, and logistic policy functions at the agency head and military component levels. Yet, the early technical activity defines the program to such an extent that most of the business posture of the program is predetermined, including the roles and relationships of the Government and industry in defining and developing the system.

At the top agency and component levels, the procurement policy side becomes actively involved in key decisions late in the acquisition process. At the agency component operating levels, however, procurement activities are involved early. As new acquisition programs are initiated, procurement must immediately begin using the contracting tools and techniques prescribed by procurement policy and regulations. These policies and regulations are intended for more orthodox, straightforward procurements and have caused problems in major systems using advanced technology. The disparity between technical and business policies can be seen from the way procurement methods and techniques have been applied in the past:

- Fixed-price contracting, incentive contract formulas, and total package procurement utilized for lengthy, uncertain system development.
- Emphasis on profit incentives to control contractor efficiency although the overriding

[67] Other organizational interests and functions at the OSD level, including intelligence, systems analysis, comptroller, and test and evaluation are represented at the three DSARC meetings.

motivations in the defense industry were for size and survival.

- Reliance on special clauses to "guarantee" product quality and total system performance responsibility when emphasis was needed on system definition and test and evaluation during development.
- Application of simple price competition (as used in conventional procurement) to complex, unique system acquisitions where technical uncertainties and company survival outweigh all other considerations.

Management attention has often focused on the contract type as a vehicle to correct acquisition problems. In the 1950's, the cost-plus-a-fixed-fee contract was used extensively. But concern developed that the cost-plus environment did not sufficiently constrain industry and criticism resulted in a move towards use of fixed-price and multiple-incentive type contracts as a management tool. The 1960's proved that use of these types of contracts resulted in a new set of problems; in reaction to these problems and attendant criticisms, the current trend is to move back to cost-type contracting.

Management by reaction cannot achieve the necessary integration of the business considerations of a system program. A rationale that technical needs and considerations must come first, followed by the business activity has created a void during program evolution. This void of business activity has allowed the technical function to make commitments that strongly affect the business structure of the program without necessarily understanding implications of those commitments. Issues such as competitive approach, technical risk, time factors, contracting, and cost should be actively considered from the start.

The foregoing problems can be alleviated by giving the business function and the technical function closely interacting roles in staff organizations from the beginning.

MANAGEMENT LAYERING AND FUNCTIONAL STAFF REVIEWS

The split between DDR&E and ASD(I&L) responsibilities contributes to an already existing pattern of management layering that extends into the agency components where multiple assignments of authority and responsibility also reside (see fig. 4).

During the past 15 years the subject of management layering and excessive functional and supporting staffs has been exhaustively documented, with only negligible improvements. A 1971 General Accounting Office study of major systems described the many organizational units that the program manager must satisfy in order to deal with top management:

> As a rule, they have no direct approval powers. They can delay or stop a project but cannot make decisions to proceed, change direction, provide money, or take other positive action.[68]

The Deputy Secretary of Defense recognized this condition:

> Changes must be made to minimize the numerous layers of authority between the program manager and the Service Secretary.[69]

A more recent GAO report cites examples of inefficiencies and delays resulting from chain of command and functional layering[70] and other studies have reported similar conditions. For example, the Logistics Management Institute found that:

> There has been an insignificant reduction in the number of layers of authority between program managers and their Service Secretaries over the past three years.[71]

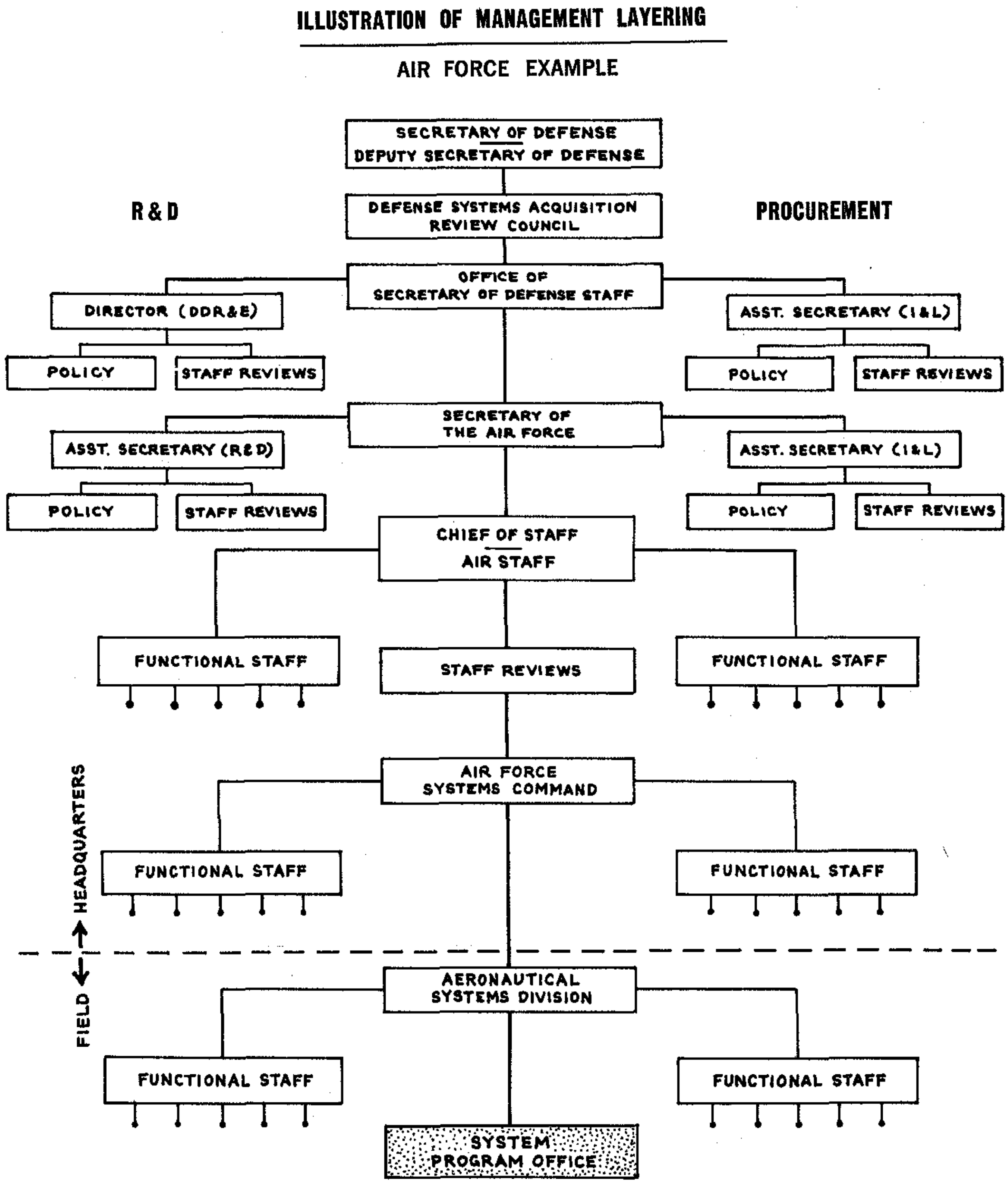
Program office organizations for major acquisition programs range from the highly integrated vertical and self-supporting types at one end, through matrix-types in the center, to lightly staffed program offices that rely on permanent functional staffs for support at the other end. The more autonomous organizations often have special reporting procedures that permit the program manager to by-pass intervening layers of management and deal directly with top management. However, this situation exists for only a few highly important programs; in most cases, program managers must go through a long chain of command as illustrated in figure 4.

[68] U.S. Comptroller General, Report B-163058, *Acquisition of Major Weapon Systems, Department of Defense,* Mar. 18, 1971, p. 51.

[69] U.S. Department of Defense, Deputy Secretary of Defense Memorandum, Policy Guidance on Major Weapon System Acquisition, May 28, 1970, p. 2.

[70] GAO Acquisition Report, 1972, note 9, *supra,* pp. 25–27.

[71] Logistics Management Institute, LMI Task 72-6, *The Program Manager Authority and Responsibilities,* Aug. 1972, summary, p. iii.



Source: Commission Studies Program.

Figure 4

Layering constrains the program manager in at least two ways. Vertical levels of management review and approval burden him directly. He also faces multiple reviews of a functional nature. For example, R&D, procurement, comptroller, facilities, and data management specialists all review actions flowing from his operation. The combination of functional and intermediate level controls, review and approval points is often cited as the cause of delays in procurement actions and program accomplishment.[72]

There is also the problem of keeping a great number of people at various agency levels informed on every program. The value of keeping each level informed is difficult to assess. Although there is no question that access to information commensurate with levels of responsibility is essential, much time and effort is required to keep each level routinely informed.

The actual impact of agency staff layering on the cost of programs is impossible to assess. Whatever it costs, it is reflected in industry and, therefore, multiplied several times. Because a contractor is required to deal proficiently with the particular specialty that each agency person represents, industry counterpart efforts result. Contractors, for example, will submit special studies and reports so that the various Government staffs will react favorably to their proposals or to their existing program. Program managers in Government and industry are aware of this costly, time-consuming phenomenon and accept it because they must keep the program going.

According to an official in one of the military services:

> We are literally suffocating from excess manning and excessive management . . . when you have more monitors than doers, the time has come to reverse the trend. I believe middle management featherbedding has become an endemic disease in the U.S., not only in industry, but in all echelons, public and private.[73]

The Senate Armed Services Committee has reported that part of the problem in DOD is overmanagement and has recommended a flat 25 percent reduction in headquarters personnel.[74]

ALTERNATIVES FOR PROGRAM OFFICE ORGANIZATION

Matrix-type program organizations are most frequently used for a major system acquisition. These organizations depend on staff members (1) assigned to permanent functional organizations which have concurrent responsibilities to support other programs and (2) staff assigned full-time to the program office. The matrix form is generally considered to be more economical for overall support of programs but to function less efficiently with respect to any one. An extra advantage is that it can draw on the experience of functional staffs specially maintained and expert in their fields.

Problems with a matrix organization arise because the program manager lacks direct authority over functional support personnel: they serve "two masters" and competition for their time and resources hinders managerial effectiveness.

The use of a strictly vertical organization (i.e. all essential personnel assigned directly to the program office) is generally reserved for those major systems of great urgency and scope. This limitation is based on the recognition that recruiting, training, and maintaining a large number of specialized personnel is difficult and expensive for a single program that will phase through a cycle of activities and eventually be disbanded.

There is disagreement over the most effective type of program office organization. Two classes of programs could be identified using criteria such as urgency, complexity, scale of resources involved, and the degree of technical responsibility to be assumed by the Government for defining and developing a new system.

The first class might be programs to meet needs of high national importance, such as the Polaris and Apollo programs. The program manager would be of high rank, would report directly to the agency head, and have a full-time staff to support him. Programs of this character require heavy Government involve-

[72] For example, GAO Acquisition Report, 1972, note 9, *supra*, p. 26.

[73] Comments, Lt. Gen. Otto Glasser, Deputy Chief of the Air Staff for Research and Development "Prototyping: Middle Management Featherbedding," *Government Executive*, 4:28, Oct. 1972.

[74] U.S. Congress, Senate, Committee on Armed Services, S. Rept. 92-962, July 14, 1972, p. 9.

ment and responsibility, a competent self-supporting staff, and a strong program manager.

The second class might be programs where contractors are given responsibility for defining the system subject to hardware test and evaluation. Here a small matrix-type organization could be used. During a competitive system development phase, the latter type organization could be very austerely manned. Large Government staffs to control and monitor should be reserved for noncompetitive system acquisitions.

MANAGING OPERATIONS

Extensive management systems, reporting, and technical data requirements have been imposed on agency personnel and contractors in what has essentially become a noncompetitive system acquisition environment. During the 1960's it was DOD policy to disengage from contractor's operations and rely more on reported information. Nevertheless, the Blue Ribbon Defense Panel estimated the cost of management systems and related data in DOD procurements in fiscal 1969 to be $4.4 billion.[75] The Assistant Secretary of the Navy (Research and Development), stated:

> . . . we have all gotten so entranced with the technique that we think entirely in terms of procedures, systems, milestone charts, PERT diagrams, reliability systems, configuration management, maintainability groups, and the other minor paper tools of the "Systems Engineer" and manager. We have forgotten that someone, some person, must be in control and must exercise his management, his knowledge and his understanding to create a system. As a result, we have developments that follow all of the rules but merely fail.[76]

To permit an orderly approach to managing extended phases of contractor operations, and to minimize the adverse effects of too much overlap of production with development, DOD currently is employing a results-oriented milestone approach to the management of system acquisition programs. A "milestone" is the successful completion of a critical phase of development. It means that a significant objective, that had the possibility of being missed, has been achieved. Milestone planning implies that a test and evaluation program is tailored to demonstrate milestone accomplishment. That is, test routines and standards are defined in advance.

Decisionmakers are interested in "milestones" because, if scheduled to test the right objectives, the supporting data will result in progressive risk reduction and indicate actual, not just planned, accomplishments. Decisions that commit funds and reduce available program options will be based on actual events, and not on arbitrary calendar dates. Time, including the initial operational capability schedule, is made a variable and contract provisions are written to provide flexibility to the Government in the event milestones are not met. The use of milestones for major system acquisitions offers considerable potential as a management tool.

The evidence to date indicates that complex management systems, extensive technical data and reporting requirements, and voluminous procurement rules have not protected the Government's interest in the vast majority of sole-source system development programs. The cumulative cost of such controls, including those reflected in industry contracts, could be used instead to fund competitive development programs.

To the extent that the principle of competitive development cannot be applied in system acquisitions, the most effective alternative is close involvement between a strong, technically competent agency program office and the contractor. Essentially, this involvement would focus on a continuous trade-off of cost against the value of achieving particular system technical requirements together with a strengthened agency test capability to evaluate system progress and milestone accomplishments.

Conclusions and Recommendations

- No single office at agency or component levels is responsible for policymaking and

[75] Blue Ribbon Defense Panel, *Report to the President and the Secretary of Defense on the Department of Defense*, appendix E, Staff Report on Major Systems Acquisition Process, July 1970, p. 45.

[76] Public statement of Hon. Robert A. Frosch, Asst. Secretary of the Navy (Research and Development), at the Institute of Electrical and Electronic Engineers, Inc., New York City, luncheon Mar. 1969.

monitoring or is accountable to the agency head for results of policy.

• Strong action is lacking to reduce management layering, overstaffing, and redundant reviews and coordinations.

• Policies that govern the structuring of new system acquisition programs and those governing the procurement tools and contracting techniques used in carrying them out are not reconciled. As a result, procurement approaches have not matched the character of technical activity embodied in major system acquisition programs.

• Program managers are usually assigned after the essential performance and cost characteristics of a major system have been defined. They therefore have no role in some of the important early decisions governing execution and success of the program for which they will be responsible.

• It is difficult for the program manager to exercise effectively the authority given him by charter due to excessive management layering and split policymaking, the functional specialists who review and approve, and management personnel who have to be kept routinely informed on major programs.

• The complex task of program management can be simplified by the recommendations in this report to defer commitments to a system until a systems-level competition has been conducted with demonstration of critical hardware.

• The primary characteristics of a program determine the best type of program office organization; i.e., the extent of priority and resources required and whether the Government defines the system and retains system responsibility or whether an industry competition is used to define the system.

• DOD has been developing program management principles and policies based on a "results-oriented" milestone approach for monitoring program progress and decisionmaking. They should be useful guides to other executive agencies.

Recommendation 11. Unify policymaking and monitoring responsibilities for major system acquisitions within each agency and agency component. Responsibilities and authority of unified offices should be to:

(a) Set system acquisition policy.

(b) Monitor results of acquisition policy.

(c) Integrate technical and business management policy for major systems.

(d) Act for the secretary in agency head decision points for each system acquisition program.

(e) Establish a policy for assigning program managers when acquisition programs are initiated.

(f) Insure that key personnel have long-term experience in a variety of Government/industry system acquisition activities and institute a career program to enlarge on that experience.

(g) Minimize management layering, staff reviews, coordinating points, unnecessary procedures, reporting, and paperwork on both the agency and industry side of major system acquisitions.

Recommendation 12. Delegate authority for all technical and program decisions to the operating agency components except for the key agency head decisions of:

(a) Defining and updating the mission need and the goals that an acquisition effort is to achieve.

(b) Approving alternative systems to be committed to system fabrication and demonstration.

(c) Approving the preferred system chosen for final development and limited production.

(d) Approving full production release.

APPENDIX A

Operational Testing of Future Defense Systems

To assess current trends in operational testing and evaluation, seven Army, nine Navy, and seven Air Force defense system programs in various stages of development and production were analyzed. These programs account for a large number of the defense systems that will be available to the military services in the 1970's, 1980's, and 1990's. Of interest is the application of the "initial OT&E" before a major production decision that is required by current policy. The military services plan further operational testing (follow-on OT&E) that will include more emphasis on developing doctrine, tactics, and training procedures and on refining maintainability and reliability data. Separate figures display the information obtained from each military service on their programs (see tables 1, 2, and 3). Following each table is a brief analysis of each program.

AIR FORCE PROGRAMS (table 1)

The C–5A, F–15, B–1, AWACS, and A–X airplanes and the Maverick and SRAM missiles were selected. Of these systems, the C–5A, Maverick, and SRAM had progressed to an advanced state prior to DOD's initiation of new test and evaluation policies. The F–15, B–1, AWACS, and A–X, however, were still in early stages of development and could be more readily affected by recent policy shifts.

C–5A Transport

Full-scale production of this aircraft was begun in 1965, before DOD had initiated its study of T&E and changed its policies. Operational testing of the C–5A did not begin until June 1970 and the final OT&E report is expected in May 1973. By that time, however, all of the aircraft will have been produced and over $3 billion spent or obligated. Because of former policies, OT&E was done too late to contribute to the defense system acquisition process. For current problems encountered with the C–5A performance, see discussion in Chapter 6 under committing to large-scale procurement concurrently with development testing.

SRAM Missile

The SRAM missile entered development several years ago and production was begun in January 1971 before DOD had implemented its new test policy. OT&E accomplished at the time of our study consisted of a single production missile launch from a modified B–52 by a SAC crew in June 1972. Full operational testing was scheduled to start in October 1972. The evaluation report will be completed in October 1973. Over $500 million will have been committed to production before OT&E test results are known.

Maverick Missile

This missile program entered development in July 1968 and followed the old pattern of full production preceding operational testing. In order to resolve some critical questions about the Maverick and to adapt the new test policy to an ongoing program, an initial OT&E

TABLE 1. INITIAL OT&E PLANNED ON CURRENT AND FUTURE AIR FORCE PROGRAMS

	C-5A [1]	*SRAM* [1]	*Maverick*	*F-15*	*B-1*	*AWACS*	*A-X*
(1) Who prepares test plan			Using command	Using command	Using command	Using command	Not yet scheduled
(2) Plan prepared			Yes	Yes	No	In process	
(3) Who does test			User/Supporter	User/Supporter	User/Supporter (Dev Assist)	User/Supporter (Dev Assist)	
(4) Type environment			Test Center & Ft. Riley	Test Center	Test Center	Test Center Seattle/Wash. Area	
(5) Type personnel			User/Supporter	User/Supporter	User/Supporter (Dev Assist)	User/Supporter (Dev Assist)	
(6) Joint-service testing planned			Yes	N/A	N/A	Yes	
(7) Evaluation report by			User/Supporter	User/Supporter	User/Supporter	User/Supporter	
(8) Evaluation report submitted to			HQ USAF	HQ USAF	HQ USAF	HQ USAF	
(9) When test performed			2/72–6/72	9/72–1/74	4/74–7/75	3/74–10/74	
(10) When report submitted			9/72	2/73	Prior to prod. decision	11/74	
(11) Production decision (DSARC III)			6/71–9/72	2/73	not scheduled	11/74	
(12) Major production authorized	10/65	1/71	7/71	3/73	7/75 (est.)	12/74	5/74 (est.)
(13) Procurement funds to be requested (millions) [2]							
Prior	2876.6	344.9	77.9	0	0	0	0
FY 73	207.6	202.5	61.2	421.6	0	0	0
To complete		250.0	55.1	5104.4		1358.7	[3]

[1] Initial OT&E not applicable. These systems were developed under the total package procurement concept; follow-on OT&E is being conducted.
[2] Weapon system procurement only—does not include development, spares, etc. Source: Presidential Budget Data.
[3] Classified data.

Source: Memorandum from the Office of the Director of Defense Research & Engineering to the Commission, subject: "Information on Operational Test and Evaluation for Commission on Government Procurement," June 8, 1972, enclosure.

was conducted from February to June 1972. The evaluation report was completed in September 1972. In the same month DSARC convened and approved a second production option.

F–15 Fighter

The development contract for the F–15 fighter was signed in January 1970 before the new DOD test and evaluation policies were implemented. Developmental flight test of the F–15 began in July 1972. It is planned to have three Air Force preliminary evaluations (development flight testing) prior to the first major production decision scheduled for February 1973. Some initial OT&E by the user is being added to these tests so an evaluation can be available at the February 1973 production decision. The contract provides for the first production options to be exercised in March 1973. OT&E tests, their evaluation, and their reporting are all scheduled to take place in January and February provided that the airplanes are available and suitable for testing. Technical problems and delays have been encountered in the development of the advanced technology engine to be installed in the aircraft. Also, the OT&E flight testing and evaluation and reporting phases are crowded into the schedule. There is only a slight possibility that the military value of the F–15, from an operational point of view, will be known in time for the initial production decision.

A second decision to go from a low to a higher rate of production is scheduled for February 1974. Much additional operational test data is scheduled to be available at that time.

B–1 Bomber

Initial OT&E, on the first B–1 prototype aircraft, is scheduled to begin in April 1974. The user command (SAC) will be a part of the test force. The production decision has not been firmly scheduled.

AWACS

AWACS is scheduled for seven months combined DT&E and OT&E before the planned production decision is made in November 1974. It is a relatively new program and embodies a competitive prototype phase for the airborne radar subsystem, the major advancement in capability required for this weapon system. The Air Force is attempting to improve the test program over the one planned earlier.

A–X Close Air Support Aircraft

This plane is the first to be developed under the new developmental prototype strategy. Two contractors are submitting prototype aircraft for a competitive flight test of operational tasks to determine the candidate to be selected for final development. Pilots of the using agency will participate in the flight test. The flight test will take place during late 1972, and the test report is expected in early 1973. The DSARC is scheduled to meet in February 1973 to decide whether to proceed with final development; the evaluation of the using command and that of the developer will be available.

ARMY PROGRAMS (table 2)

The Cheyenne helicopter, the Heavy Lift Helicopter, the Utility Tactical Transport Aircraft System (UTTAS), and the Dragon, Improved Hawk, SAM–D, and Lance missiles were selected. The Heavy Lift Helicopter, UTTAS, and SAM–D are relatively new and have production decisions coming up in the middle or late 1970's.

Lance

The Lance is a surface-to-surface missile system to provide fire support to Army corps and divisional forces. Although development was initiated earlier, the program was re-

TABLE 2. INITIAL OT&E PLANNED ON CURRENT AND FUTURE ARMY PROGRAMS

	Lance [1]	*Imp. Hawk* [1]	*Dragon* [1]	*Cheyenne* [1]	*SAM-D*	*Heavy Lift Helicopter*	*UTTAS*
(1) Who prepares test plan	User representative	User representative	User representative	C A	User representative	Not yet scheduled	User representative
(2) Plan prepared	Yes	Yes	Yes	N	In process		In process
(3) Who does test	Developer with user participation	Developer with user participation	Developer with user participation	C E	Developer with user participation		User representative
(4) Type environment	Test Center	Test Center	Test Center	L	Test Center		To be det.
(5) Type personnel	User	User	User	L	User		User
(6) Joint-service testing planned	N/A	No	N/A	E D	Yes		N/A
(7) Evaluation report by	User representative	User representative	User representative		User representative		User representative
(8) Evaluation report submitted to	HQ DA	HQ DA	HQ DA	D U	HQ DA		HQ DA
(9) When test performed	8/71–3/72	[3]	1/72–11/72	R	[3]		10/75–11/72
(10) When report submitted	4/72	[3]	2/73	I	[3]		To be det.
(11) Production decision (DSARC III)	4/71	7/70	[3]	N G	[3]		To be det.
(12) Long-leadtime	8/71	[2]	[2]		[3]		9/76
(13) Major production authorized	6/72	1/72	[3]	S	[3]		4/77
(14) Procurement funds to be requested (millions)[4]				T U			
Prior	136.3	308.4	15.3	D	0		0
1973	90.1	106.0	56.5	Y	0		0
To complete	75.5	219.7	300.5				

[1] Ongoing programs prior to establishment of current T&E policies.
[2] Not applicable.
[3] Classified data.
[4] Weapon system procurement only—does not include development, spares, etc.

Source: Memorandum from the Office of the Director of Defense Research & Engineering to the Commission, subject: "Information on Operational Test and Evaluation for Commission on Government Procurement," June 8, 1972, enclosure.

oriented in 1967 to provide a longer-range missile. An initial OT&E was combined with development tests conducted between August 1971 and March 1972. Full-scale production of most system components was approved in June 1972, following review of the developmental test and initial OT&E results.

Improved Hawk

The Improved Hawk is to be a low and medium altitude air defense system. It contains modifications to various components of the basic Hawk system plus an all new solid-state missile and a computerized information-coordination system for automatic engagement of enemy aircraft. Development was begun in the mid-1960's prior to initiation of the current DOD test and evaluation policies. Various reliability and performance problems were encountered during the developmental test programs. To provide additional missiles for test and to establish the training base, a limited production contract for improved Hawk missiles and battery modification kits was awarded in June 1969. A second contract was awarded with fabrication and assembly of modified missile components to be restricted until satisfactory test results were achieved. The modified components were satisfactory and the restriction was lifted. A third production contract was awarded in 1972. The initial OT&E on this system will be conducted in a period (classified) following these dates and a report will be submitted. By the time that operational test results are known, over $400 million will have been committed to the program.

Dragon

The Dragon is to be a man-portable anti-tank missile system with the missile guided to the target by electronic commands through a wire link. Combined developmental and initial OT&E tests of the Dragon were being conducted during 1972. A production decision is scheduled at a later date (classified).

Cheyenne Helicopter

The Cheyenne helicopter was one of the total package procurements awarded in the 1960's. Technical difficulties were encountered during development and production was terminated. The 1973 budget request included money to complete development, to update two original R&D prototypes, and to complete a production model. Congress did not authorize the money and the Army is now planning a new helicopter program.

SAM–D

The SAM–D missile is to be a surface-to-air defensive missile to defend against enemy airborne weapons. It is intended to replace the Improved Hawk missile discussed above and the Nike Hercules. Expanded service testing, scheduled for the SAM–D by the developing activity, will be combined with an initial OT&E. Long-leadtime production items will be authorized at completion of the test and full production of the missile is planned to start about 1–1/2 years later.

Heavy Lift Helicopter

The Heavy Lift Helicopter is in the initial stages of development. Procurement funds have not yet been requested. No schedule has been established for the initial OT&E although some simulated operational testing could be made at this early stage to judge the potential operational effectiveness of the prototype helicopter and its specifications.

UTTAS

The Utility Tactical Transport Aircraft System (UTTAS) will be designed to transport infantry squads. Competitive prototypes will be developed first. A year's testing of the prototype is to begin late in 1975. The test program will combine developmental flight testing and an initial OT&E. Production is scheduled for April 1977.

NAVY PROGRAMS (TABLE 3)

The Mark 48–1 torpedo, S–3A Viking, F–14 Tomcat, and the Sparrow and Phoenix missiles were the ongoing programs selected. The Harpoon antiship missile, the Condor missile, the Vulcan Phalanx cannon, and the CH–53 helicopter were the newer programs selected.

Mark 48–1 Torpedo

The MK 48 was a long-range antisubmarine torpedo. After some difficulties in development during the 1960's, the Navy added a second competing contractor to develop the MK 48–1 with an antiship capability. In 1971 the Navy selected the second contractor as the production source. Late that year the MK 48–1 entered production. Although a policy requiring an initial OT&E was not in effect prior to the production decision, data the Navy furnished indicate that torpedo tests were made under operational conditions prior to the production decision.

S–3A Viking

The Navy S–3A is an antisubmarine aircraft. The contract awarded in 1969 was a total package procurement combining development, testing, and production. The Navy met several times with OSD officials to obtain approval of a production decision (DSARC III) and this approval was received in April 1972. Developmental flight tests also started in 1972. OT&E personnel will participate in the developmental testing and then are expected to start their own flight tests in January 1973. The second production decision is planned for February 1973. Testing will continue through the next year with a final report due in September 1974. The initial OT&E test to be used for the second production decision will be limited and the schedule is tight. Approximately $600 million in procurement will have been committed to the program by that time.

AIM 7F Sparrow Missile

This missile is a solid-state version of the AIM 7E. It is expected to provide improved reliability, range, and lethality over early Sparrow models. Development commenced in 1966 but procurement go-ahead has been delayed because of technical performance problems encountered in the developmental test program. In February 1971, an OSD decision was made to keep the missile in R&D an additional year and expand the developmental test program. This has since been completed and the missile is currently in a joint Navy-Air Force OT&E with completion scheduled for late 1972. At that time a DSARC meeting will be held to decide if to proceed into full-scale production.

Condor

The Condor is a medium-range supersonic cruise missile that uses electro-optical guidance with data link to find various ground targets. The completion date of initial OT&E of test articles of this missile is classified. However, during the month of test completion: (1) an evaluation must be made, (2) a report prepared and submitted to the Chief of Naval Operations, (3) the report evaluated, (4) a production decision reached at OSD level (DSARC), and (5) contract terms executed authorizing production.

F–14 Tomcat

The F–14A is to be the Navy's air superiority fleet air defense fighter. It is also expected to have an air-to-surface attack role. A total package procurement contract for this aircraft was negotiated in 1968 and there is considerable overlap among development, test, and production. The OSD approval (DSARC) of initial production occurred in September 1970. This contract contains annual production release dates and priced out production options that must be executed if renegotiation of the contract is to be avoided. The Navy's develop-

TABLE 3. INITIAL OT&E PLANNED ON CURRENT AND FUTURE NAVY PROGRAMS

	MK 48-1 Torpedo [1]	*S-3A Viking* [1]	*Sparrow III, AIM-7F* [1]	*Condor*	*F-14 Tomcat* [1]
(1) Who prepares test plan	Developer with user participation	Developer with user participation	OT&E organization	OT&E organization	Developer with user participation
(2) Plan prepared	Yes	Yes	Yes	No	Yes
(3) Who does test	Developer with user participation	Developer with user participation	OT&E organization	Developer with user participation	Developer with user participation
(4) Type environment	At sea	Navy operational	Various combat modes	Air to surface	Navy operational
(5) Type personnel	Developer & user	Developer & user	User	OT&E organization	Developer & user
(6) Joint-service testing planned	N/A	N/A	Yes (with AF)	AF flight crew will participate	N/A
(7) Evaluation report by	OT&E organization	OT&E organization	OT&E organization	OT&E organization	OT&E organization
(8) Evaluation report submitted to	CNO	CNO	CNO	CNO	CNO
(9) When test performed	3/71	5/72–8/73	11/72 (completed)	[2]	12/71–6/73
(10) When report submitted	6/71	1/73 initial 10/73 final	12/72	[2]	12/71 initial 8/73 final
(11) Production decision (DSARC III)	7/71	4/72	12/72	[2]	9/70
(12) 1st long-leadtime production release	Unknown	4/71	None	[2]	4/70
(13) Major production authorized (contract signed)	10/71	4/72	1/73	[2]	9/70 (exercised 1st prod. option)
(14) Procurement funds to be requested (millions) [3]					
Prior	427.3	369.3	327.8	0	1298.1
1973	156.5	581.1	83.1	13.0	483.5
To complete	973.3	1201.9	747.6	174.1	1539.3

[1] Program information should not be construed to respond to DOD Directive 5000.1 for Initial Operational Test and Evaluation (IOT&E) requirements. These programs were already under contract, they do not follow the classic development route specified in DOD Directive 5000.1.

[2] Classified data.

[3] Weapon system procurement only—does not include development, spares, etc. (Congressional Data Sheet Item P-1 plus advanced procurement.)

Source: Memorandum from the Office of the Director of Defense Research & Engineering to the Commission, subject: "Information on Operational Test and Evaluation for Commission on Government Procurement, June 8, 1972, enclosure.

TABLE 3. INITIAL OT&E PLANNED ON CURRENT AND FUTURE NAVY PROGRAMS—Continued

	Phoenix Missile[1] *AIM–54*	*Harpoon Anti-Ship Weapon System*	*Vulcan Phalanx*[3]	*CH–53E*
(1) Who prepares test plan	OT&E organization	OT&E organization	OT&E organization	OT&E organization
(2) Plan prepared	Yes	Yes	In process	In process
(3) Who does test	OT&E organization	OT&E organization	OT&E organization	OT&E organization
(4) Type environment	Various air-air	At sea	At sea	Navy operational
(5) Type personnel	OT&E organization	User	Dev/OT&E org.	OT&E org./user
(6) Joint-service testing planned	N/A	N/A	N/A	N/A
(7) Evaluation report by	OT&E organization	OT&E organization	OT&E organization	OT&E organization
(8) Evaluation report submitted to	CNO/SECNAV	CNO	CNO	CNO
(9) When test performed	7/72–6/73	[4]	5/73–5/74	10/75
(10) When report submitted	8/72 initial 8/73 final	[4]	6/74	10/75 preliminary 12/75 final
(11) Production decision (DSARC III)	9/70	[4]	5/74	10/75
(12) 1st. long-leadtime production release	None	[4]	7/72	12/74
(13) Major production authorized (contract signed)	12/71	[4]	6/73–12/73	10/75
(14) Procurement funds to be requested (millions)[2]		Not yet determined	Not yet determined	Not yet determined
Prior	262.7			
1973	94.8			
To complete	663.3			

[1] Program information, *op. cit.*
[2] Weapon system procurement only—*op. cit.*
[3] Program currently under review. Dates are tentative.
[4] Classified data.

Source: Memorandum from the Office of the Director of Defense Research & Engineering, to the Commission, subject: "Information on Operational Test & Evaluation for Commission on Government Procurement," June 8, 1972, enclosure.

mental flight test program started in late 1971 and has disclosed major deficiencies.[1]

The Navy's independent operational test activity will test components of aircraft numbers 16 and 17 and all of aircrafts 18 and 19. The operational test agency's request for an earlier aircraft was refused. Operational evaluation is to commence in late 1972 and continue through 1973. The OT&E report will not be available until about three years after the production decision.

A sound operational evaluation of the F–14A is more critical today than it was initially. The advanced technology engine to provide greater thrust for the "B" version of the aircraft encountered serious technical problems and delays and will not be available as planned.

There has been some controversy in the Navy concerning the possible need for a much lighter, more maneuverable aircraft to combat the latest enemy aircraft. The principal reason for the heavier aircraft is the incorporation of the Phoenix missile to be discussed next.

Phoenix Missile

The Phoenix is to be a supersonic, all-weather, long-range, air-to-air missile to provide the F–14 aircraft with a stand-off capability against attacking aircraft. It is intended to have a simultaneous launch capability against six targets in an all-weather, heavy jamming environment. Like the F–14 contract, the total package procurement contract for the Phoenix missile was written before the current DOD test policy went into effect. Initial operational testing is not expected to be completed until mid-1973 or about 1 1/2 years after the major production go-ahead.

Because the F–14 concept depends heavily on the Phoenix missile, an early, realistic test of that missile's capability in operational environments seems important.[2]

[1] DOD 1973 Appropriations Hearings, part 7, pp. 563–565.

Harpoon

Procurement funds have not as yet been requested from Congress for this antiship missile weapon system. The present plan is to request authorization for pilot-line production (classified) with a full production decision to be made (classified) after development and operational tests are made on missiles from the pilot-line production.

Vulcan-Phalanx Close-in Weapon System

Initial OT&E of the Vulcan-Phalanx is planned to commence in May 1973 using a preproduction prototype and will be continued using initial production units when they become available. Initial OT&E tests will be completed in May 1974 and a decision at the OSD level regarding full production will be made at that time. The report on operational evaluation is not scheduled to be available until June 1974.

CH–53 Helicopter

Several prototypes will be developed and tested under this new program. An initial OT&E is planned to be completed in October 1975 with use of a preliminary report in the production decision. A final report is due in December 1975. Production decisions are scheduled to be made in October 1975 and authorized by contract during the same month.

[2] For example, if the F–14A and its missiles are unable to cope with fast maneuvering fighters, its survivability in combat is in question.

APPENDIX B

List of Recommendations

Establishing Needs and Goals

1. Start new system acquisition programs with agency head statements of needs and goals that have been reconciled with overall agency capabilities and resources.

   (a) State program needs and goals independently of any system product. Use long-term projections of mission capabilities and deficiencies prepared and coordinated by agency component(s) to set program goals that specify:

   (1) Total mission costs within which new systems should be bought and used

   (2) The level of mission capability to be achieved above that of projected inventories and existing systems

   (3) The time period in which the new capability is to be achieved.

   (b) Assign responsibility for responding to statements of needs and goals to agency components in such a way that either:

   (1) A single agency component is responsible for developing system alternatives when the mission need is clearly the responsibility of one component; or

   (2) Competition between agency components is formally recognized with each offering alternative system solutions when the mission responsibilities overlap.

2. Begin congressional budget proceedings with an annual review by the appropriate committees of agency missions, capabilities, deficiencies, and the needs and goals for new acquisition programs as a basis for reviewing agency budgets.

Exploring Alternative Systems

3. Support the general fields of knowledge that are related to an agency's assigned responsibilities by funding private sector sources and Government in-house technical centers to do:

   (a) Basic and applied research

   (b) Proof of concept work

   (c) Exploratory subsystem development. Restrict subsystem development to less than fully designed hardware until identified as part of a system candidate to meet a specific operational need.

4. Create alternative system candidates by:

   (a) Soliciting industry proposals for new systems with a statement of the need (mission deficiency); time, cost, and capability goals; and operating constraints of the responsible agency and component(s), with each contractor free to propose system technical approach, subsystems, and main design features.

   (b) Soliciting system proposals from smaller firms that do not own production facilities if they have:

   (1) Personnel experienced in major development and production activities

   (2) Contingent plans for later use of required equipment and facilities.

   (c) Sponsoring, for agency funding, the most promising system candidates selected by agency component heads from a review of those proposed, using a team of experts from inside and outside the agency component development organization.

5. Finance the exploration of alternative systems by:

   (a) Proposing agency development budgets according to mission need to support the exploration of alternative system candidates.

   (b) Authorizing and appropriating funds by agency mission area in accordance with review of agency mission needs and goals for new acquisition programs.

   (c) Allocating agency development funds to components by mission need to support the most promising system candidates. Monitor components' exploration of alternatives at the agency head level through annual budget and approval reviews using updated mission needs and goals.

6. Maintain competition between contractors exploring alternative systems by:

   (a) Limiting commitments to each contractor to annual fixed-level awards, subject to annual review of their technical progress by the sponsoring agency component.

   (b) Assigning agency representatives with relevant operational experience to advise competing contractors as necessary in developing performance and other requirements for each candidate system as tests and tradeoffs are made.

   (c) Concentrating activities of agency development organizations, Government laboratories, and technical management staffs during the private sector competition on monitoring and evaluating contractor development efforts, and participating in those tests critical to determining whether the system candidate should be continued.

Choosing a Preferred System

7. Limit premature system commitments and retain the benefit of system-level competition with an agency head decision to conduct competitive demonstration of candidate systems by:

   (a) Choosing contractors for system demonstration depending on their relative technical progress, remaining uncertainties, and economic constraints. The overriding objective should be to have competition at least through the initial critical development stages and to permit use of firm commitments for final development and initial production.

   (b) Providing selected contractors with the operational test conditions, mission performance criteria, and lifetime ownership cost factors that will be used in the final system evaluation and selection.

   (c) Proceeding with final development and initial production and with commitments to a firm date for operational use after the agency needs and goals are reaffirmed and competitive demonstration results prove that the chosen technical approach is sound and definition of a system procurement program is practical.

   (d) Strengthening each agency's cost estimating capability for:

      (1) Developing lifetime ownership costs for use in choosing preferred major systems

      (2) Developing total cost projections for the number and kind of systems to be bought for operational use

      (3) Preparing budget requests for final development and procurement.

8. Obtain agency head approval if an agency component determines that it should concentrate development resources on a single system without funding exploration of competitive system candidates. Related actions should:

   (a) Establish a strong centralized program office within an agency component to take direct technical and management control of the program.

   (b) Integrate selected technical and management contributions from in-house groups and contractors.

   (c) Select contractors with proven management, financial, and technical capabilities as related to the problems at hand. Use cost-reimbursement contracts for high technical risk portions of the program.

(d) Estimate program cost within a probable range until the system reaches the final development phase.

System Implementation

9. Withhold agency head approval and congressional commitments for full production and use of new systems until the need has been reconfirmed and the system performance has been tested and evaluated in an environment that closely approximates the expected operational conditions.

(a) Establish in each agency component an operational test and evaluation activity separate from the developer and user organizations.

(b) Continue efforts to strengthen test and evaluation capabilities in the military services with emphasis on:

(1) Tactically oriented test designers

(2) Test personnel with operational and scientific background

(3) Tactical and environmental realism

(4) Setting critical test objectives, evaluation, and reporting.

(c) Establish an agencywide definition of the scope of operational test and evaluation to include:

(1) Assessment of critical performance characteristics of an emerging system to determine usefulness to ultimate users

(2) Joint testing of systems whose missions cross service lines

(3) Two-sided adversary-type testing when needed to provide operational realism

(4) Operational test and evaluation during the system life cycle as changes occur in need assessment, mission goals, and as a result of technical modifications to the system.

10. Use contracting as an important tool of system acquisition, not as a substitute for management of acquisition programs. In so doing:

(a) Set policy guidelines within which experienced personnel may exercise judgment in selectively applying detailed contracting regulations.

(b) Develop simplified contractual arrangements and clauses for use in awarding final development and production contracts for demonstrated systems tested under competitive conditions.

(c) Allow contracting officials to use priced production options if critical test milestones have reduced risk to the point that the remaining development work is relatively straightforward.

Organization, Management, and Personnel

11. Unify policymaking and monitoring responsibilities for major system acquisitions within each agency and agency component. Responsibilities and authority of unified offices should be to:

(a) Set system acquisition policy.

(b) Monitor results of acquisition policy.

(c) Integrate technical and business management policy for major systems.

(d) Act for the secretary in agency head decision points for each system acquisition program.

(e) Establish a policy for assigning program managers when acquisition programs are initiated.

(f) Insure that key personnel have long-term experience in a variety of Government/industry system acquisition activities and institute a career program to enlarge on that experience.

(g) Minimize management layering, staff reviews, coordinating points, unnecessary procedures, reporting, and paperwork on both the agency and industry side of major system acquisitions.

12. Delegate authority for all technical and program decisions to the operating agency

components except for the key agency head decisions of:

(a) Defining and updating the mission need and the goals that an acquisition effort is to achieve.

(b) Approving alternative systems to be committed to system fabrication and demonstration.

(c) Approving the preferred system chosen for final development and limited production.

(d) Approving full production release.

APPENDIX C

Supplemental Views of a Commissioner*

The major systems acquisition report contains many statements and recommendations which are deserving of full support. Certain topics, however, merit elaboration in order that they may be thoroughly considered in any ensuing implementation of such recommendations.

The topics of public sector/private sector roles, subsystem development, system integration, and total acquisition strategy are discussed as follows, both generally and as specifically related to major ship acquisition programs.

Public Sector/Private Sector Roles

The report advances the thesis that measurable improvement will most likely result from increasing competition at the conceptual stage between industry participants. To capture such potential improvement, however, sufficiently different conceptual solutions to given problems must exist to warrant extended competition prior to selecting and pursuing a preferred alternative. Such situations may not comprise a majority—in which case attention should be directed as well toward those situations which may more frequently be encountered. Sole-source procurement may be more judicious in a number of varying circumstances, in which case the Government's interests are best protected through strong program control over participating contractors.

As discussed in the basic text, design is a key ingredient in any program effort; hence, the argument for reliance wherever possible upon private sector sources for competitive designs. The text concludes that private sector efforts can be expected to produce superior results; and, notwithstanding the incidence of situations where in-house design effort is necessary, further recommends that the role of in-house laboratories be generally restricted to:

—Planning and conducting test and evaluation of systems being developed by private sources.

—Monitoring development and production programs carried out by the private sector.

Constricting the role of Government laboratories in such a way reverses a constructive trend begun as a result of the 1962 Bell Report.[1] With specific regard to DOD laboratories, DOD has selectively initiated and pursued a weapon center concept following endorsement of that concept in 1966 by the Defense Science Board and the President's Science Advisory Committee.[2]

The broadening of the DOD laboratory system responsibilities to fully encompass the weapon center concept should be continued and consideration given to further actions under the concept to include:

—Reduction in total number of DOD laboratory facilities through consolidation where feasible, but not to the extent that competition between centers in like areas of endeavor would be destroyed.

—Operation of each center, under a local director within a total facility budget enve-

*Commissioner Sanders.

[1] U.S. Congress, Senate Report to the President on Government Contracting for R&D. Bureau of the Budget Document No. 94, May 17, 1962.

[2] DOD Office of the Director of Defense Research and Engineering. Management Analysis Report 70–1, "The Defense In-House Laboratories," September 15, 1970, pp. 18–20.

lope, with manpower and facility controls imposed only as a result of the facility budget. Laboratory directors should possess the flexibility and administrative tools to integrate people, program funds, facilities, and equipment in the most cost-effective manner without additional externally imposed constraints.

—The joint use of Government facilities and co-related personnel assets as a corporate entity by all of the individual laboratories should be encouraged and pursued.

—The center approach should be structured so that individuals can freely cycle back and forth between such centers, the universities, and private firms as their specific interests and abilities fluctuate along with varying levels of program effort.

—DOD should give consideration to initiating a few experiments in which the management of existing laboratories is changed to Government-owned/contractor operated or quasi-public owned and operated facilities.

—Increased participation in mutually beneficial international exchange situations.

The following additional observations are pertinent relative to the R&D center concept:

First: Whereas the report text addresses the value of industry competition during the conceptual and developmental phases of a planned program, a strong internal capability must also be judiciously maintained in order that the Government can itself properly address the question of what its needs are. An internal capability to pursue a wide-ranging R&D program simply for the sake of exploration is essential to the maintenance of a proper defense capability. A coherent R&D center structure can contribute toward such capability and at the same time minimize problems associated with stewardship of the public tax dollars.

Second: Close and continuous communication between operational users and idea innovators in Government as well as in industry is essential to an optimum developmental process. The R&D center approach facilitates such communication in that it encourages direct dialogue between the two parties without prejudicing contractual relationships. Operation of the center as envisioned, on a gross annual budget basis, as opposed to project by project, facilitates pacing of effort to match desired changes in emphasis, permits greater transferability of talent, expertise, and learning from one project to another as successive efforts are undertaken, and provides the opportunity for a growing reservoir of understanding, by all personnel involved, of the operational needs, versus the technology available or projected to meet such needs.

Third: Expansion of the R&D center structure, as envisioned, has the potential for permitting savings through personnel reductions. Pursuit of conceptual and various types of prototype development effort by small, dedicated design teams within and among the R&D centers would permit substantial reductions in the size and degree of involvement of numerous functional staffs throughout the various Governmental organizational hierarchies.

Ship Acquisition Process

(System Development and Subsystem Integration)

The basic text advances the argument that subsystem development should not be independently pursued through full-scale development without such subsystem being a planned integral part of some larger system development. The rationale for such argument is that premature full-scale system development unduly constrains the total system development and tends to precipitate sub-optimum system/subsystem integration. The thesis generally fits in a *context* where technological advancement is rapid. In certain other areas, the state of the art, as in most ship hull types, and their support components, is not in the same category. Most hulls for naval ships, for instance, may well have reached their evolutionary plateau. Further, such hulls generally are expected to have life expectancies which exceed by a factor of 2 or 3 the life expectancies of the several generations of weapon systems such ship types are expected to transport during their 20–30 year lifetime. An area for major consideration then, to ensure thorough and proper design, is the capability of ships to accommodate successive generations of weapon systems with relative ease and reasonable expense. Such an environment logically argues for considerable full-scale development of subsystems and componentry, independent of any particular ship hull type with which such subsystems may subsequently be integrated.

The Navy faces a particular problem in that manpower considerations dictate that designers seek a total ship system which requires less total manpower. Unfortunately, this adds complexity to hardware, which in turn generates *reliability and maintainability problems,* and therefore maintenance manpower problems—a vicious cycle which is not susceptible to being easily or quickly broken. Integration of a set of complex weapon systems within a hull system, while at the same time making reasonable provision for future systems, demands more than the admonition carried in the basic text to restrain full-scale subsystem development until system integration can be achieved. Pursuit of subsystem development to whatever extent feasible—dependent upon the characteristics of the specific subsystem/system concerned—coupled with increased subsystem developmental and operational test and evaluation, appears to be a more reasoned total approach.

Total Acquisition Strategy

Closely related to the above discussion of system integration are problems which flow from the various ways in which responsibility for design is handled in ship acquisition programs. The fundamental problem of determining whether the Government, the contractor, or some mixture of both assumes design responsibility is generally well discussed in the basic text. The problem, however, is compounded in shipbuilding due to: (a) the extremely long leadtimes involved in the design/construction process, and (b) the general desirability of having more than one shipyard involved in construction of a given ship type (for mobilization reasons as well as those benefits which accrue from possibly shortened leadtimes). A dilemma exists in that attempts to shorten delivery leadtimes by contracting for two or more yards to work concurrently create problems relative to design responsibility and essential commonality of the products after delivery. On the other hand, long series production runs solve part of the design responsibility problem by facilitating in process corrections to defects, but create others in the form of "feast" for one yard, "famine" for others. This is so, regardless of where the responsibility for design rests. Thus, decisions as to actual design, where such responsibility is placed, how many yards are to be involved, and the number of ships to be constructed critically impact both the customer and the industry as a whole. Numerous acquisition strategies, therefore, suggest themselves and the Navy has utilized many such approaches in the process of acquiring ships over the years.

The acquisitions of the 50's were characterized by a large number of different classes being built. Discrete orders were generally made each program year and both public and private yards were utilized—generally no more than three ships of a series type being constructed in any one yard. This general strategy was employed as a result of there being enough work to go around and the existence of a strong in-house design capability. Ships were simple compared to those of today and builders had only to more or less follow directions. Relations were good between the parties, and disputes, when they arose, were generally satisfactorily resolved, as issues were relatively clear and the contracts flexible and relatively short in duration.

There were advantages in such a mode of operation, but results were not all favorable. An extreme lack of part standardization occurred from which the Navy has not fully recovered. The small backlog situation restrained contractors from making needed capital improvements. Finally, there was a growing opinion that the ship designs were not optimal and that improvement would result from greater involvement by the builders in ship design.

The early 60's saw the initiation of the five-year defense planning concept which tended to force acquisition programs to become fewer in number, but larger in size. The same time frame witnessed widespread use of firm fixed-price contracts even in developmental, risk-type work, with price being the primary basis for award. This situation, (large awards to single producers), coupled with certain overcapacity resulted in cost, schedule, and quality of product problems which manifest themselves in the form of claims. The breakdown in communication generally inherent in a claim situation results in further degradation of effort and concerted effort on the part of all concerned is necessary to rectify a claim environment. Identification of potential claim situations constitutes a first step in any improvement effort. Continued use of the controversial "anticlaims" provisions, now being included in most ship acquisition contracts, is therefore on balance probably desirable, notwithstanding negative industry reaction. The thrust of the use of such clauses should be toward identifying potential claim situations and ensuring that differences of opinion are resolved and adjustment to contract totals negotiated accordingly before such differences become unmanageable.

Current trends toward separate development and production contracts hold promise over problems inherent in the acquisition strategies employed previously. Such separation, coupled with construction by more than one shipbuilder under flexible contract arrangements, may lessen certain problems associated with the earlier strategies. Underlying factors of shipyard facility obsolescence and industry overcapacity, however, are not susceptible to easy solution.

A recognized need exists for shipbuilding industry modernization; however, private incentives to modernize are lacking for two reasons: first, production contracts are not in hand, and second, sufficient planning is not being accomplished on the part of the Government buyer to assure a reasonably accurate and stable forecast of future needs. Modernization associated with award of certain production contracts carries with it the risk of production schedule delays; hence for the Government the risk either must be assumed or different types of incentives must be provided to stimulate facility investment and modernization in advance of award of production contracts.

Although firm contracts provide the most positive incentive, certain investment would likely result given a visible, reasonably stable and believable overall picture of future ship acquisition programs. Elements of such a picture exist, however they are loosely coordinated and lack full development. In essence, no recognized, overall plan exists to coordinate needs versus total shipyard capability or to properly guide the Government and industry in decisions of great magnitude to both.

Further effort should be undertaken by appropriate Governmental agencies, the shipbuilding industry and other representation as might be advisable.

APPENDIX D

Acronyms

ACP	Area Coordinating Paper
AEC	Atomic Energy Commission
AF	Air Force
AFSC	Air Force Systems Command
AMC	Army Materiel Command
AR	Army Regulation
ARPA	Advanced Research Projects Agency
ASD	Assistant Secretary of Defense
ASD (I&L)	Assistant Secretary of Defense for Installations and Logistics
ASPR	Armed Services Procurement Regulation
ASW	Antisubmarine Warfare
AWACS	Airborne Warning and Control System
CDC	Combat Developments Command
CNO	Chief of Naval Operations
DA	Department of the Army
DCA	Defense Communications Agency
DCAA	Defense Contract Audit Agency
DCP	Development Concept Paper
DCS	Deputy Chief of Staff
DDC	Defense Documentation Center
DDR&E	Director of Defense Research and Engineering
DOD	Department of Defense
DSARC	Defense System Acquisition Review Council
DT&E	Development Test and Evaluation
ECP	Engineering Change Proposal
FCRC	Federal Contract Research Center
FPR	Federal Procurement Regulations
FY	Fiscal Year
GAO	General Accounting Office
GFE	Government Furnished Equipment
GOR	General Operational Requirement
HQ	Headquarters
IAC	Industry Advisory Council
I&L	Installations and Logistics
ICAF	Industrial College of the Armed Forces
ICBM	Intercontinental Ballistic Missile
IDA	Institute for Defense Analyses
IOC	Initial Operational Capability
JCS	Joint Chiefs of Staff

JFM	Joint Forces Memorandum
JRDOD	Joint Chiefs Research and Development Objective Document
JSOP	Joint Strategic Objectives Plan
LMI	Logistics Management Institute
LOGO	Limitation of Government's Obligation
MBT	Main Battle Tank
MCA	Military Construction Appropriation
NASA	National Aeronautics and Space Administration
NASA PR	National Aeronautics and Space Administration Procurement Regulations
NATO	North Atlantic Treaty Organization
NMC	Naval Material Command
OPNAV	Office of the Chief of Naval Operations
OPTEVFOR	Operational Test and Evaluation Force
OSD	Office of the Secretary of Defense
OT&E	Operational Test and Evaluation
PM	Program Memorandum
POM	Program Objectives Memoranda
PR	Procurement Regulations
PTA	Proposed Technical Approaches
QMR	Qualitative Materiel Requirement
R&D	Research and Development
RDT&E	Research, Development, Test and Evaluation
ROC	Required Operational Capability
SAC	Strategic Air Command
SAM–D	Surface-to-Air Missile Development
SAMSO	Space and Missile System Organization
SECNAV	Secretary of the Navy
SOR	Specific Operational Requirement
SRAM	Short-Range Attack Missile
SUPSHIPS	Supervisor of Shipbuilding (Navy)
T&E	Test and Evaluation
TCP	Technology Coordinating Paper
TSOR	Tentative Specific Operational Requirement
TSPR	Total System Performance Responsibility
USAF	United States Air Force
USN	United States Navy
USSR	Union of Soviet Socialist Republics
UTTAS	Utility Tactical Transport Aircraft System
WPAFB	Wright Patterson Air Force Base
WSEG	Weapon Systems Evaluation Group